



UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C. 20460

OFFICE OF
PREVENTION, PESTICIDES
AND TOXIC SUBSTANCES

Note to Reader

Background: As part of its effort to involve the public in the implementation of the Food Quality Protection Act of 1996 (FQPA), which is designed to ensure that the United States continues to have the safest and most abundant food supply. EPA is undertaking an effort to open public dockets on the organophosphate pesticides. These dockets will make available to all interested parties documents that were developed as part of the U.S. Environmental Protection Agency's process for making reregistration eligibility decisions and tolerance reassessments consistent with FQPA. The dockets include preliminary health assessments and, where available, ecological risk assessments conducted by EPA, rebuttals or corrections to the risk assessments submitted by chemical registrants, and the Agency's response to the registrants' submissions.

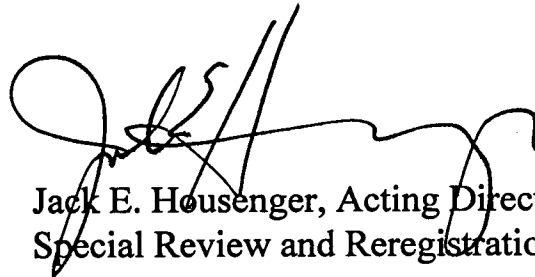
The analyses contained in this docket are preliminary in nature and represent the information available to EPA at the time they were prepared. Additional information may have been submitted to EPA which has not yet been incorporated into these analyses, and registrants or others may be developing relevant information. It's common and appropriate that new information and analyses will be used to revise and refine the evaluations contained in these dockets to make them more comprehensive and realistic. The Agency cautions against premature conclusions based on these preliminary assessments and against any use of information contained in these documents out of their full context. Throughout this process, If unacceptable risks are identified, EPA will act to reduce or eliminate the risks.

There is a 60 day comment period in which the public and all interested parties are invited to submit comments on the information in this docket. Comments should directly relate to this organophosphate and to the information and issues available in the information docket. Once the comment period closes, EPA will review all comments and revise the risk assessments, as necessary.

These preliminary risk assessments represent an early stage in the process by which EPA is evaluating the regulatory requirements applicable to existing pesticides. Through this opportunity for notice and comment, the Agency hopes to advance the openness and scientific soundness underpinning its decisions. This process is designed to assure that America continues to enjoy the safest and most abundant food supply. Through implementation of EPA's tolerance reassessment program under the Food Quality Protection Act, the food supply will become even safer. Leading health experts recommend that all people eat a wide variety of foods, including at least five servings of fruits and vegetables a day.

Note: This sheet is provided to help the reader understand how refined and developed the pesticide file is as of the date prepared, what if any changes have occurred recently, and what new information, if any, is expected to be included in the analysis before decisions are made. **It is not meant to be a summary of all current information regarding the chemical.** Rather, the sheet provides some context to better understand the substantive material in the docket (RED chapters, registrant rebuttals, Agency responses to rebuttals, etc.) for this pesticide.

Further, in some cases, differences may be noted between the RED chapters and the Agency's comprehensive reports on the hazard identification information and safety factors for all organophosphates. In these cases, information in the comprehensive reports is the most current and will, barring the submission of more data that the Agency finds useful, be used in the risk assessments.

A handwritten signature in black ink, appearing to read 'J. Housenger', is written over the typed name and title.

Jack E. Housenger, Acting Director
Special Review and Reregistration Division

Malathion Reregistration Eligibility Document

Environmental Fate and Effects Chapter

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Introduction

Limitations and Agreements With Registrants Regarding the Uses and Application Scenarios Reviewed and Supported

Registrants who presently intend to support reregistration of malathion products have been contacted and informed that only those use rates presently supported by food tolerances will be reviewed for this Reregistration Eligibility Document. Those crops where tolerances do not exist or where no support from registrants has been received by the Agency are considered revoked and will not be addressed in EFED's risk assessments for Malathion reregistration. Non-food uses of Malathion will be reviewed as has been done with previous REDs. Worst case risk presumptions will be based on the maximum labeled rates, maximum permitted seasonal applications and minimum recommended intervals for these use patterns. The Cheminova and IR-4 Malathion teams have presented proposed uses and application scenarios they intend to support.— Any labels which exceed the rates or permitted maximum seasonal applications, or that specify minimum application intervals which are less than the rates presented by these groups will require additional environmental assessment and review.

Temporal Uncertainties of Tolerance Test Scenario Use In Risk Assessments

Assumptions of lower use rates, longer intervals, and limited numbers of seasonal applications based on maximum tolerance tested rates may lead to prediction of lower risk potential than what will occur when mandatory label revisions are in progress. Some malathion labels presently permit application rates well in excess of maximum tolerance rates of 6.25 lb ai/A (8.0 to 25.0 lbs ai/acre presently listed on several product labels). The time limits for revision of existing labels will impact the currency of the present assessment for malathion impacts on wildlife and aquatic organisms. This may be tempered by the fact that higher rates, shorter intervals, and unlimited seasonal applications are not as economically practical for the user community and for that reason not common practice. However, given the number of uses and products containing malathion and the number of registrants producing these products, it is expected that application restrictions and mitigation measures may not be implemented for several years pending final agreements with registrants.

Use Characterization

Historical Perspective

Malathion has been used for 45 years and is manufactured in over 50 locations throughout the world. Though malathion has been manufactured by a variety of companies, the technical formulation portion of the U.S. business was purchased by Cheminova Agro from American Cyanamid in 1991. As of 1994, all technical malathion used in the U.S. is marketed and distributed by Cheminova.

Summary of Supported Product Types, Formulations, and Use Scenarios

Product Numbers, Types and Percent Active Ingredient

Technical malathion is produced by Cheminova Agro for the U.S. market. At this time 63 formulators of pesticide products use malathion as an active ingredient. Approximately 235 malathion products are produced by these 63 formulators. Some of these products also contain active ingredients other than malathion (e.g., methoxychlor).

Product types include technical ingredient for formulation use, emulsifiable concentrates, wettable powders, dusts, and ready to use (RTU) formulations. There are no granular malathion products presently registered, although malathion is used in a variety of bait type formulations or mixed and applied to food baits for attraction of target insects.

The percent of malathion employed in these 235 products varies considerably and ranges from less than 3% for many of the homeowner use RTU's to as high as 96% malathion for ULV formulations.

Use Scenarios

The majority of agricultural and public health uses involve the mixture or dilution of EC formulations with water for aerial or ground spray application to target areas either as ULV applications, standard ground application sprays, or ground fogs. Wettable powders are generally diluted in 1 to 100 gallons of water and applied to plant surfaces by ground spray methods. Dust formulations are often used for treatment of grain storage areas or the actual grain itself. Ready to use formulations are often used in the home and applied directly to the insect pest or to areas where the pest is observed. Uses of malathion for direct application to livestock is not being supported. Forest uses on public lands are not being supported, though use on tree farms is still permitted.

Summary of Major Uses Nationwide

Cheminova has divided the malathion market into four major portions; USDA special program use, commercial agriculture, public health use, and home and garden use. Actual tonnage use estimates are considered confidential business information, the percentages of use can be broadly summarized as USDA, 59-61%; General Agriculture, 16-20%; Public Health, 8-15%; and home and garden use, 10%. These percentages of use may vary with fluctuations in pest pressure or concerns for public health which might occur following natural disasters, e.g. a hurricane.

Summary of USDA Special Program Uses

The Boll weevil Eradication Program for cotton crops in the lower states account for the greatest

proportion of use by USDA as well as the nation as a whole. Over 97% of USDA's uses of malathion have been towards efforts to eradicate the Mexican boll weevil from U.S. cotton crops. In 1997 USDA applied over 10 million pounds of malathion active ingredient primarily by aerial ULV methods to areas of infestation in Texas and Alabama. Large portions of Texas, Louisiana, Mississippi, and Alabama are targeted for 1998. States where heavy infestations have been eradicated, but lower preventative uses are sometimes still employed, include California, Arizona, Georgia, South Carolina, North Carolina, and Virginia. In general, 10-12 oz. of product (about 1.0 lb of active ingredient) are aerially applied 6-8 times per acre before, during and after the cropping season.

Other programs comprising about 2% of USDA malathion use include the Mediterranean Fruit Fly Control Programs in Florida and California and Grasshopper Control on Federal Rangelands in the western states. Nationwide USDA use has ranged from 80,000 to 360,000 lbs of ai for these programs depending on pest sightings or pressure. Medfly applications generally involve mixture of malathion into a hydrolysate bait at about a 20% malathion concentration which is then applied two to four times at 0.175 lb ai/acre by aircraft or ground spray equipment.

Summary of Public Health Uses

Mosquito control in populated and rural areas comprises the major use of malathion for public health uses. In general, public health use would be necessitated by actual disease outbreak caused by a particular pest. Though mosquito control does potentially prevent such outbreaks (particularly after hurricanes or major storms) much of the application is also performed for economic reasons. This type of use is particularly heavy near coastal resort areas, where high bite rates constitute a potential loss of tourist revenue and therefore an incentive for active spraying programs. High use of adulticides is generally an indication that larvicidal uses of pesticides during the early breeding season have failed to control population outbreaks.

Summary of Supported Agricultural Crop Uses

Approximately 100 food crop uses of malathion are being supported by Cheminova and IR-4. In the past many labels have often **not** reflected the application rates, intervals, and maximum numbers of application on which acceptable tolerance levels were based. Many of the over 250 product labels were written with no specified intervals or limitations on the numbers of applications which could be made to crops. In an effort to standardize the acceptable label rates for reregistration purposes, Cheminova and IR-4 have agreed to specify maximum rates, minimum intervals, and maximum seasonal application numbers that they support for food uses (see table which follows). Crop scenario codes are indicated by letters for each separate application rate (lbs ai/A), followed by numbers for maximum proposed multiple applications, and (number of days) for the intervals proposed between applications. Thus A10 (7D) indicates an application of 0.175 lbs ai/A is permitted 10 times during the growing season with a minimum interval between applications of 7 days. Many crops may fall under the same application scenario or in some cases only one crop is proposed for that particular scenario. These scenarios are later used in EEC and Risk Quotient tables and allow the reader to associate each value with a particular crop or use pattern.

Table 1.

Malathion Use Rate Table - Crop Scenarios
Cheminova and IR4 Supported Maximum Tolerance Rates

	Number of Applications												
	Rate lb ai/A	Int. Day	1	2	3	4	5	6	7	8	9	10	12- 25
A	0.175	7D	A1									A10(7D)	
B	0.50	NA	B1										
B	0.61	5D	C1				C5(5D)						
C	0.61	7D		C2(7D)	C3(7D)								
C	0.61	14D		C2(14D)									
D	0.76	10D	D1				D5(10D)						
E	0.94	3D	E1			E4(3D)							
E	0.94	6D						E6(6D)					
E	0.94	7D			E3(7D)								
F	1.0	7D	F1					F6(7D)					
G	1.25	3D	G1	G2(3D)				G6(3D)					G25 (3D)
G	1.25	5D					G5(5D)						
G	1.25	7D		G2(7D)	G3(7D)	G4(7D)	G5(7D)	G6(7D)	G7(7D)	G8(7D)	G9(7D)	G10(7D)	
G	1.25	14D		G2(14D)									
H	1.50	7D			H3(7D)		H5(7D)						
I	1.56	7D		I2(7D)				I6(7D)					
J	1.88	5D					J5(5D)						
J	1.88	7D			J3(7D)	J4(7D)		J6(7D)					
J	1.88	14D		J2(14D)									
K	2.03	6D						K6(6D)					
K	2.03	7D			K3(7D)	K4(7D)							
L	2.5	3D											L25 (3D)
L	2.5	5D			L3(5D)								
L	2.5	7D			L3(7D)		L5(7D)						
M	3.43	5D					M5(5D)						
N	3.75	7D				N4(7D)		N6(7D)					

N	3.75	14D				N4(14D)							
	Rate lb ai/A	Int. Day	1	2	3	4	5	6	7	8	9	10	12- 25
O	4.7	30D		O2(30D)									
P	5.0	7D			P3(7D)	P4(7D)							
Q	6.25	30D			Q3(30D)								

0.175 lb ai/A	A10=Orange, Grapefruit, Lemon, Lime, Tangerine, Tangelo, and Kumquat
0.50 lb ai/A	B1=Flax
0.61 lb ai/A	C5(5D)=Sweet Corn , C2(7D)=Hops, C3(7D)=Beans, Corn, Rice, Sorghum, Wheat, and Rye C2(14D)=Alfalfa, Clover, Lespedeza, Lupine and Vetch
0.76 lb ai/A	D5=Blueberry
0.94 lb ai/A	E1(3D)=Grass for hay, E4(3D)=Mushroom, E6(6D)=Strawberry, E3(7D) =Peppermint and spearment, E7(7D)=Macadamia
1.0 lb ai/A	F6(7D)=Melons, Watermelon, Pumpkin and Winter Squash
1.25 lb ai/A	G1(3D)=Grass for hay, G2(3D)=Field corn , G2(7D) Brussel sprouts, cauliflower, collards, kale, kohlrahi G6(3D)=Mustards, G25(3D)=Cotton, G5(5D)=Watercress, G3(7D)=Rice, Sorghum, Wheat, Rye, Barley, Oats and Corn, G4(7D)=Blueberry(ULV), G5(7D)=Turnip, Broccoli, Apple, Sweet Corn, Beet, Chayote , Horseradish, Parsnip, Radish, Rutabaga, Salsify, Sweet potato , G6(7D)= Cabbage and Cherry(ULV), G7(7D)=Carrot , G8(7D)=Mango and Passion fruit , G9(7D)=Asparagus G10(7D)=Pears and Quince , G12(7D)=Guava and Papaya, G2(14D)=Alfalfa, Clover, Lupine, Vetch nd Lespedenza
1.5 lbs ai/A	H2(7D)=Celery, H6(7D)=Okra
1.56lbs ai/A	I2(7D)=Potato, Sweet potato, I5(7D)=Onion, Garlic, Shallot, Leeks
1.88 lb ai/A	J6(5D)=Lettuce, J4(7D)=Blackberry, Raspberry, Loganberry, Boysenberry, Dewberry, Currant, Gooseberry, J3(7D)=Cucumber, Chayote, J6(7D)= Strawberry, J2(14D)=Grapes
2.03 lbs ai/A	K6(6D)=Strawberry(50% WP), K3(7D)= Spinach, Dandelion, Endive, Parsley and Swiss Chard, K4(7D)=Blackberry, Raspberry, Gooseberry, Loganberry, Dewberry, Currant and Boysenberry
2.50 lb ai/A	L25(3D)=Cotton, L3(5D)=Figs, L3(7D)=Mustards, Walnuts, and Pecans, L5(7D)=Peas
3.43 lb ai/A	M5(5D)=Tomato, Pepper, Eggplant
3.75 lb ai/A	N4(7D)=Apricots, N6(7D)=Cherry, N4(14D)=Peach and Nectarine
4.7 lb ai/A	O2(30D)=Avocado
5.0 lb ai/A	P3(7D)=Pineapple, P4(7D)=Chestnuts
6.25 lb ai/A	Q3(30D)=Oranges, Grapefruit, Lemon, Lime, Tangerine and Tangelo

Commercial Non Food Crops

Malathion is presently supported for registration on several non-food crops. These crops include ornamental flowering plants, ornamental lawns and turf, nursery stock plants, ornamental woody plants, pine seed orchards, Christmas trees(commercial), and slash pine.

Previous non-food crop uses which are not being supported by Cheminova or IR-4 include forest uses on douglas fir and spruce(for spruce budworm), hemlock(for hemlock looper), pine trees(for european pine sawfly & Saratoga spittlebug) and larch(for larch casebearer). No registrant has indicated support for reregistration of malathion for tobacco and therefore it is assumed this use will be revoked.

Non-Crop Uses-Agriculture Related

Storage of Grains: Malathion 6% dust formulation is being supported for treatment of stored corn, wheat, barley, oats and rye.

Livestock Feed Lots and Holding Pens: Though direct applications to livestock are no longer supported, treatments of holding facilities and feed lots are still being supported. These treatments are primarily for control of flies and mosquitoes and may be used as sprays or in bait formulations.

Beet Leafhopper Control-Non-Agricultural Lands: This program is confined to specific target areas on non-agricultural lands to control the spread of this pest. The use appears on the Fyfanon ULV and 8EC labels (page 2).

Grasshopper Control Non-Federal Lands: These programs are carried out to control aphids, grasshoppers, and leafhoppers in pasture and rangeland. The Fyfanon 8EC label specifies a mixture of malathion with diesel fuel.

Fly Control-Cull Fruit and Vegetable Dumps: Fyfanon labels contain this use to control drosophila flies and dried fruit beetles around vegetable and fruit dumps. The 8EC label specifies application as a concentrated drench.

Summary of Other Non-agricultural Uses

Commercial Use Urban Scenarios

Homeowner Use: Malathion is formulated into numerous home and garden sprays for non commercial use on vegetables, fruit trees, ornamental plants and flowering shrubs, turf, and outside structures. Many are ready to use sprays or dusts and many are combined with other active ingredients.

Use Around Commercial Buildings and Warehouses

Malathion is used to treat for a number of nuisance pests around warehouses, storage yards, inside buildings, outside perimeters of commercial buildings, etc

Table 2.

MALATHION NON AGRICULTURAL USE SUMMARY

USE LOCATION WHERE RATE APPLIES (MAX RATE in lbs ai/A)	Max. Rate	Max # Applic.	Min. Interv.	Predicted U.S. Acreage (EPA/OPP)
Nonagricultural rights of way/fencerows/hedgerows	0.598	NS	NS	17,000
Mosquito Control Lakes/Ponds/Reservoirs(human use)(0.5985) Nonag. Uncultivated Areas/Soils (0.6) Polluted Water (0.6) Lakes/Ponds/Reservoirs (No Human Use) (0.628) Swamps/Marshes/Wetlands/Stagnant Water (0.628) Intermittently Flooded Areas/Water (0.628)	0.630	NS	NS	8,227,000
Woodland Use Pine Forest/Shelterbelt (0.9375) Eastern White Pine (Forest) (0.9375)	0.94	NS	NS	17,000
Rangelands/Pastures/Set Aside Acreage/Summer Fallow Canarygrass (1.2) Rangeland or Pastures (1.25) Grass Forage/Fodder/Hay (1.25)	1.25	NS	NS	1,625,000
Ornamental Plant Uses-Nurseries-Homeowner Ornamental trees and Herbaceous Plants	1.746	NS		175,000
Ornamental Nonflowering Plants Ornamental Woody Shrubs and Vines (2.5)	2.50	NS	NS	
Commercial Tree Production Christmas Tree Plantations, (3.125) Ornamental and/or Shade Trees (3.125) Slash Pine (forest) (3.125)	3.125	NS	NS	No estimate provided
Public Parks				67,000
Turf Use/ Golfcourses/Commercial Lawncare Ornamental Lawns and Turf	5.1	NS	NS	35,000 (golfcourses + cemeteries) Commercial landscape= no estimate provided
Total Non-Ag Use per Year-4,100,000 lbs ai/year (USEPA OPP/BEAD estimates)				

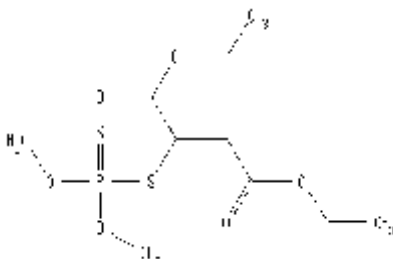
NS=Not Specified

Exposure Characterization

Environmental Fate and Chemistry of Malathion

A. Chemical Profile

O,O-Dimethyl phosphorodithioate of diethyl mercaptosuccinate



Physical/Chemical properties:

Molecular formula:	C₁₀H₁₉O₆PS₂.
Molecular weight:	330.3 g/mol.
Physical state:	Clear amber liquid.
Melting point:	2.85° C.
Boiling point (0.7 mm Hg):	156-157° C.
Specific gravity (25° C):	1.23
Vapor pressure (30° C):	4 x 10⁻⁵ mm Hg.
Solubility (25°C):	145 mg/l water.

B. Environmental Fate Summary

Wildlife and humans may be exposed to malathion and its degradates through contamination of food, water, and air (by suspended particles) which can result from off-target drift, runoff, and direct application. Increased toxicity may be brought about through oxidation (to malaoxon) and isomerization (to isomalathion). Limited data is available on toxic degradates and impurities, but the fate data on malathion is acceptable and shows little persistence. Based on registrant data and open literature reports, EFED concludes that the primary route of dissipation of malathion in surface soils appear to be microbially mediated soil metabolism (half-life <1-2.5 days) and hydrolysis (pH 7 half-life 6.21 days and pH 9 half-life 12 hours) with malathion monoester, ethyl hydrogen fumarate, diethyl thiosuccinate, malathion mono- and dicarboxylic acids, demethyl mono- and dicarboxylic acids, and CO₂ as known degradates.

Other important routes of dissipation from soil suggested by the data include leaching, plant uptake, and surface runoff. Malathion and its degradates in general are soluble and do not adsorb strongly to soils. Data from the field dissipation studies indicate that malathion dissipates rapidly when applied in the field. Although the anaerobic and aerobic aquatic metabolism and aquatic field dissipation studies indicate very rapid degradation ($T_{1/2} = <2.5$ days), the metabolism studies were performed under alkaline conditions that favor hydrolysis and the water pH in the dissipation study was not specified. As such it is difficult to separate out the effect of hydrolysis from metabolism.

Malathion is stable to hydrolysis at pH 5 ($T_{1/2} = 107$ days), to aqueous photolysis ($T_{1/2} = 94$ and 143 days, corrected for dark control) and soil photolysis ($T_{1/2} = 173$ days) and does not volatilize appreciably ($\leq 5.1\%$ of applied volatilized after 16 days). Open literature studies suggest persistence on soil is longer under dry, sandy, low nitrogen, low carbon, and acidic conditions (Walker and Stojanovic 1973).

Acceptable leaching data on parent malathion indicate that it is mobile in all soils tested (K_d s = 0.82-2.47). Acceptable terrestrial field dissipation data indicate rapid dissipation ($T_{1/2} = <2$ days). One detection of malathion below 12 inches was found in a terrestrial field dissipation study, indicating leaching as a likely route of dissipation. Similarly, column leaching studies demonstrated that malathion and its degradates, malathion mono- and dicarboxylic acids are very mobile in soil. Data presented to the Agency and in the "Pesticides and Groundwater Database" (U.S. Environmental Protection Agency 1992) demonstrate that malathion has the potential to leach to ground water. Malathion has been detected in ground water in three states (California, Mississippi, and Virginia) at levels ranging from 0.03 to 6.17 ppb. Based on these data and the low K_d values for malathion it is clear this chemical has the potential to leach to ground water.

Some fate and toxicity data are also available on other malathion degradates and impurities. Technical malathion contains impurities that account for up to 5% of the insecticide. CalEPA has reported 15 impurities present in a representative ultra low volume malathion formulation. These impurities include

diethyl fumarate (0.90%)
diethylhydroxysuccinate (0.05%)
O,O-dimethylphosphorothioate (0.05%)
O,O,O-trimethyl phosphorothioate (0.45%)
O,O,S-trimethyl phosphorodithioate (1.20%)
Ethyl nitrite (0.03%)
Diethyl-bis (ethoxycarbonyl) mercaptosuccinate (0.15%)
S-1,2-ethyl-O,S-dimethyl phosphorodithioate [isomalathion] (0.20%)
S-(1-methoxycarbonyl-2-ethoxycarbonyl)ethyl-O,O-dimethyl phosphorodithioate (0.60%)
Bis-(O,O-dimethyl thionophosphoryl) sulfide (0.30%), Diethyl methylthiosuccinate (1.00%)
S-ethyl-O,O-dimethyl phosphorodithioate (0.10%)
S-1,2-bis (ethoxycarbonyl) ethyl-O,O-dimethyl phosphorothioate [malaoxon] (0.10%)
diethyl ethylthiosuccinate (0.10%)

sulfuric acid (0.05%).

Several of these organophosphate impurities potentiate malathion toxicity and also are toxic alone, but there is almost no data available on their environmental fate. The persistence of one highly toxic phosphorothioate impurity was shown to be 18.7 times longer than malathion in a aerobic soil metabolism study (Miles and Takashima 1991). Phosphorothioates and -dithioates have been intensively studied and induce a delayed toxic effect to mammals at much lower levels than pure malathion (Ali Fouad and Fukuto 1982, Umetsu *et al* 1977, Fukuto 1983, Aldridge *et al* 1979, Toia *et al* 1980). One hydrolysis product, diethyl fumarate (sometimes referred to as DEF), which is also present as an impurity in technical malathion is approximately 3 times more toxic to fathead minnows than malathion (Bender 1969). No registrant submitted fate data and little open literature data exist for impurities of malathion.

The relative concentration of malathion impurities can vary dramatically depending on manufacturing processes and storage conditions. Umetsu *et al* (1977) concluded:

“Storage of technical malathion for 3 to 6 months at 40 degrees C resulted in materials which were noticeably more toxic to mice.”

“Needless to say, malathion should not be stored for prolonged periods under conditions where it is subjected to consistently high temperatures.”

Regarding the impurities present in formulations from different sources of malathion, Mulla *et al* (198 state:

“One of these toxic impurities was isomalathion which was 0.3% in brand I (U.S.), 2.1% in brand II (Italian), and 3.1% in brand III (Italian).”

Thus, the composition and toxicological properties of the technical product is affected by initial quality and storage conditions.

One impurity of malathion is the oxon analog, malaoxon, which is also the active acetylcholine- esterase inhibiting component *in vivo*. Under some dry and microbially inactive environmental conditions malaoxon is formed from malathion at levels up to 10.7% of the total applied (CalEPA 1993). Monitoring studies conducted during medfly control programs show high levels of malaoxon (greater than 328 ppb) in runoff water (CDFG 1988). EFED does not have a complete environmental fate database for malaoxon but based on its chemical similarity to malathion (sulfur is replaced by oxygen), the parent and its degradate are expected to have similar chemical properties. The aerobic half-life of malaoxon has been reported as 3 and 7 days in basic and acidic soils, respectively (Paschal and Neville 1976). This longer half-life relative to malathion is proposed to be a result of malaoxon’s biocidal effect on soil microbes which contribute to malathion’s degradation.

Requirements

Data for the aerobic aquatic metabolism studies are considered supplemental at this time. The deficiency of this study is the alkaline pH of the soil and water used. Degradation of malathion is high pH dependent, with faster rates at higher pH. Thus, a quantitative assessment of malathion fate and persistence under acidic conditions when hydrolysis would be slower cannot be conducted. As a result, EFED cannot complete a quantitative assessment of the environmental fate of malathion and its degradates in acidic environments it is likely to contact. An aerobic metabolism study (162-4) performed under pH conditions that do not favor hydrolysis is requested as EFED believes this additional information will enable a more quantitative assessment of the fate and persistence of this major use chemical in acidic aquatic environments. This request is especially relevant given the sensitivity of numerous aquatic organisms to malathion.

Although the anaerobic aquatic metabolism study was also conducted under alkaline conditions favoring hydrolysis, EFED believes that hydrolysis data along with open literature data on the persistence of malathion in sediments is sufficient to conclude that malathion will not persist under anaerobic conditions. However, an anaerobic aquatic metabolism study under acidic conditions may be requested if more quantitative data on malathion degradation and degradates is needed.

Fate data is required for malaoxon, the oxidation product of malathion. Malaoxon is commonly believed to be the neuroactive toxic agent of malathion after oxidation *in vivo* and toxicity data show it to have higher acute toxicity than malathion. EFED acknowledges that maximal malaoxon conversion under registrant submitted study conditions was low (1.8%) however under other conditions encountered during malathion use conversion levels as high as 10.7% of applied insecticide have been reported (CalEPA 1993). HED also has indicated that malaoxon is to be included in the tolerance expression for malathion. First tier surface water assessments were performed by making several assumptions about the properties of malaoxon relative to malathion. It is not possible to perform second tier assessments without further information specific to malaoxon; thus, EFED requests data required to predict malaoxon levels in drinking water and aquatic habitats.

In addition to data on the basic physical properties of malaoxon (solubility, partition coefficient, vapor pressure), EFED requests that the following laboratory studies be submitted for malaoxon based on the brief justification provided. Data from these studies are expected to be sufficient to perform basic fate and exposure modeling of malaoxon.

Degradation

161-1 (hydrolysis)

Malathion hydrolysis is an important route of dissipation under alkaline conditions. The phosphorothiolate ester bond of malaoxon may be more susceptible to cleavage via hydrolysis than the analogous phosphorodithioate ester in malathion.

Metabolism

162-1 (aerobic soil) The primary route of malathion degradation on soil is through aerobic metabolism. An open literature study (Paschal and Neville 1976) suggests malaoxon persistence may

be greater on soils. Additionally, CalEPA studies have shown levels of malaoxon production exceeding 10% in certain dry, low organic content soils.

162-4 (aerobic aquatic)

Although little or no malaoxon production is observed in registrant submitted aquatic studies malaoxon has been detected in surface waters and the potential for malaoxon runoff may be heightened relative to malathion because it is expected to have higher solubility. Aerobic aquatic metabolism contributes greatly to malathion degradation.

Mobility

163-1(leaching/adsorption)

EFED is not aware of reports of malaoxon groundwater contamination. However, malathion has contaminated groundwater in several states and has the potential to contaminate surface water through runoff. The increased polarity of malaoxon due to the substitution of oxygen for sulfur increases the expected potential of this chemical to be mobile in soil.

EFED also requests additional information on environmental malaoxon production. Because malathion is used in a large number of settings including more than 60 terrestrial field uses as well as outdoor residential uses including mosquito, Mediterranean fruitfly, and urban pest control uses, it is exposed to large variety of environmental conditions. This extensive use is likely to result in significant exposure nontarget organisms to malathion breakdown products. Exposures to humans and wildlife may be through contamination of food, water, and air (by suspended particles) which can result from off-target drift, runoff, and direct application.

It is clear that under many circumstances malathion degrades rapidly to compounds of lower toxicity, usually through microbial metabolism and hydrolysis. However, in residential uses (*e.g.* aerial and ground application for mosquito control), it is likely that malathion will contact dry, microbially inactive and low organic content surfaces such as concrete, asphalt, dry soil, roofing material, and glass. It is expected that malaoxon production will be increased on these surfaces as malathion is exposed to air for extended periods until it is washed away by rain. This is supported by malaoxon monitoring data in urban streams after residential malathion treatment showing similar or higher levels of malaoxon than malathion in some instances (State of California Department of Food and Agriculture, 1982). Thus EFED proposes that malathion persistence and degradation on anthropogenic surfaces be examined (suggestions from the registrant are invited for particular surfaces to be examined). The State of California EPA has published two studies describing adequate methods for determining malaoxon production on dry soil (CalEPA 1993) and steel sheets (CalEPA 1996) which would be amenable to other abiotic surfaces. Both of these studies showed higher malaoxon production than registrant submitted studies, but maximal levels of malaoxon production were not achieved. On the steel surface : rainfall event removed most of the malathion after only 2 days. On the dry soil malaoxon production did not decrease by the time the study was terminated at 22 days. Runoff of residential malathion and

malaoxon greatly increases risk of human and aquatic wildlife exposure through drinking water and habitat contamination and increases the need for this information.

The State of California EPA has published a study describing malaoxon production on low organic content soil (0.6%) with a moisture content less than 1% (CalEPA 1993) showing higher malaoxon production than registrant submitted studies using soils with higher organic (2-2.7%) and moisture (75 of water holding capacity, capacity not stated) content. From the CalEPA data it appears that malaoxon production is favored on dry soils and thus may represent a higher risk scenario for malaoxon production and runoff. EFED believes that data on dry soils may be useful to assess malathion and malaoxon fate and persistence in some use settings which are not ideal for malathion degradation, thus EFED requests the submission of data on malathion degradation and malaoxon production in an aerobic soil metabolism study (162-1) using a soil with a low moisture content (<1%) and low organic content (<1%).

Conclusions

Malathion is generally nonpersistent, however EFED lacks important information to evaluate the behavior of malathion under acidic aquatic conditions which might likely increase its persistence and alter degradates produced. To adequately determine the environmental fate of malathion and its degradates aerobic aquatic metabolism data under acidic soil and water conditions are needed. Data are also required on the oxidative degradate malaoxon. Presently EFED has no registrant submitted fate data for malaoxon. Monitoring data suggest that malaoxon production is an important issue in residential areas. Thus, EFED is requesting studies of malathion degradation and malaoxon production on anthropogenic surface which 1.) make up much of the residential environment, 2.) increase malathion persistence, 3.) increase malaoxon production, and 4.) increase runoff potential. Acceptable data on malaoxon solubility, hydrolysis, vapor pressure, soil metabolism, and aquatic metabolism in conjunction with information on malaoxon production under high risk conditions will aid EFED in predicting environmental malaoxon concentrations for ecological and human health concerns.

Environmental Fate and Transport Studies

Degradation

Hydrolysis:

Several open literature studies (Mulla *et al* 1981, Howard 1991) are consistent with data presented by the registrant showing that malathion is unstable under alkaline conditions and increasingly stable under acidic conditions. Hydrolysis products characterized by the registrant and in the open literature are similar as well. Muhlman and Shrader (1957) report primary products of diethyl fumarate and dimethyl phosphorodithioic acid in base while the registrant's study identifies malathion monocarboxylic acid as

ethyl hydrogen fumarate. The reported differences are relatively minor as ethyl hydrogen fumarate is a expected hydrolysis product of diethyl fumarate and the other products are also expected.

In the registrant's study [^{14}C]malathion was hydrolytically stable in aqueous buffered pH 5 (half-life = 107 days) solutions. At pH 7 and 9 solutions malathion hydrolyzed relatively rapidly with half-lives of 6.21 days and 12 hours, respectively. Parent malathion accounted for 80.3% and 3.7% of applied after 28 days in the pH 5 and 7 solutions, respectively; while after 53 hours of hydrolysis at pH 9, only 3.6% of applied was parent malathion.

The hydrolysis data requirement is satisfied. (MRID 40941201, 43166301)

Photodegradation in water:

Open literature reports and registrant submitted data suggest that photodegradation in natural and distilled water is relatively slow. Open literature half-life data ranges from 0.67 (natural river water) to 42 days (distilled water) (Howard 1991).

In the registrant submitted aqueous photolysis study, [2,3- ^{14}C]malathion degraded with calculated half-lives (corrected for dark control degradation) of 94 and 156 days in sterile pH 4 photosensitized (1% acetone) and nonsensitized aqueous buffer solutions, respectively, that were irradiated continuously with a xenon arc lamp at 25 ± 1 °C for 30 days. Detections of monoethyl maleate, diethyl maleate, malaoxon, mono-acid, diethyl mercaptosuccinate, and diethyl fumarate were noted at concentrations $<<10\%$ of applied.

The photodegradation in water data requirement is satisfied. (MRID 41673001, 43166301)

Photodegradation on soil:

Registrant and open literature data suggest malathion is stable under sunlight. Open literature on photodegradation of malathion in thin films on glass showed production of 6 degradates but at a maximum level of 0.01% after 16.5 hours (Chukwudebe *et al* 1989).

In the registrant submitted soil photolysis study, [2,3- ^{14}C]malathion degraded with a registrant-calculated half-life of 173 days. The soil used was a pH 6.5 sandy loam. No degradates at concentrations $\geq 10\%$ were observed. Thus, soil photolysis is not an important route of dissipation for malathion.

The photodegradation on soil data requirement is satisfied at this time (MRID 41695501, 43166301), but EFED requests that the registrant provide an explanation for the long persistence of malathion in irradiated and dark control samples. Soils were stated to possess microbial activity which would lessen persistence making it unclear why malathion was stable under the study conditions.

Photodegradation in air:

The relatively low vapor pressure of malathion suggests gas phase reactions are only minor routes of degradation. However, malathion in the form of very small droplets (~10 µm), such as might result from ULV formulation application, may reach much higher concentrations in air. No open literature references on photodegradation in air were found.

In a the registrant supported photolysis in air study, >10% [2,3-¹⁴C]malathion, contained in Tedlar bags, degraded during 4 days of irradiation. The photolysis in air data requirement is not satisfied, however, EFED agrees with the registrant that the study should not be required for several reasons. In the laboratory volatility study, less than 5% of malathion was volatilized from soil surfaces, indicating that obtaining a significant vapor flux that can be experimentally studied for true vapor photolysis is inherently difficult. In addition, the UV absorption spectrum of malathion shows an onset of absorption at about 260 nm, well below the 290 nm cutoff for natural sunlight irradiation and for the xenon light source used in the study. Thus, photodegradation of malathion in air is not expected. This conclusion is also supported by the lack of photodegradation in either the aqueous photolysis or the soil photolysis studies. Finally, as noted in the Rejection Rate Analysis (EPA 1993), this study often generates data that are difficult to interpret, and EPA has dramatically reduced the instances in which this study is required.

Metabolism

Aerobic Soil Metabolism:

Aerobic soil metabolism is an important route of malathion degradation. Malathion persistence under aerobic soil conditions has been examined in several open literature studies which are reviewed in Table 3. Reported half-life values (from field and laboratory studies) vary from hours to 11 days. Persistence is decreased with microbial activity, moisture, and high pH.

Table 3.

Source	Degradation Rate Value	Comments
Miles and Takashima 1991	$t_{1/2} = 8.2$ h (laboratory) $t_{1/2} = 2$ h (field)	malathion was mixed with Lihue soil and incubated at 22°C in lab experiment. Sterilization decreased rate 2-fold.
Walker and Stojanovic 1974	47-95% at 7 days	malathion was incubated with various <i>Arthrobacter</i> species. Degradation in the presence of the 5 most efficient species was reported.

Walker and Stojanovic 1973	$t_{1/2} = \sim 2$ days under non-sterile unfavorable degradation conditions.	Three Mississippi soils were examined at 25-26°C. Soil microflora were important in degradation. Slowest degradation occurred in soils with low nitrogen, moisture, carbon content and increased acidity.
CalEPA 1994	DT50 = 4.2-6.9 days on sand	Measured at five sites under the conditions of the medfly eradication program. Each site consisted of 10 aluminum trays containing 500g of playground sand. Between applications trays were covered.
CalEPA 1993	DT50 < 12 h on sand	Application was under controlled conditions but temperature was not noted.
CalEPA 1993	soil: 38% remaining at 12 hours 15% remaining at 20 days	66% sand, 24% silt, 10% clay, 0.78% water, pH 6.3. Malathion was applied under controlled conditions. Degradation was biphasic.
Kearney <i>et al</i> 1969	75-100% degradation in 1 week	Field persistence
Lichtenstein and Schultz 1964	85% dissipation in 3 days	Conducted under field conditions
Handbook of Environmental Fate and Exposure Data for Organic Chemicals 1991	Reported average literature $t_{1/2} = 6$ d	In this review persistence is stated to vary with moisture content and pH.
USDA	$t_{1/2} = 3$ days used for modeling	This value was chosen for modeling malathion in the boll weevil eradication program based on a personal communication with a previous malathion registrant.

In the registrant submitted study [2,3-¹⁴C]malathion degraded with a calculated half-life of approximately 0.2 days in two aerobic metabolism experiments using loam soil (pH 6.1) incubated in the dark at $22 \pm 2^\circ \text{C}$ and 75% of field capacity. An ancillary experiment was conducted to determine the rate of degradation of malathion in sterile soil. At 4 days posttreatment, malathion comprised close to 100% of the applied radioactivity (97.84% of the extractable radioactivity). This indicates that microorganisms are important in the rapid degradation of malathion in soil under acidic aerobic conditions (MRID 41721701, 43166301).

Numerous degradates were identified in the soil extracts and are identified below as a percent of applied radioactivity: dicarboxylic acid of malathion-18.7-36.7%, the beta monocarboxylic acid of malathion-2.8-7.3%, the alpha monocarboxylic acid of malathion-1.9-2.5%, and malaoxon-0.6-1.8%.

Soil bound (unextracted) residues averaged 32% of applied at the 6 hour sampling, which increased to 65% at the 24 hour samples and then slowly decreased to 39% after 92 days of incubation. Total $^{14}\text{CO}_2$ evolution was 45-56% of the applied radioactivity; while volatile organic residues were $\leq 0.2\%$.

The aerobic soil metabolism require is considered satisfied (MRID 41721701, 43166301).

Anaerobic Aquatic Metabolism:

A open literature study (Bourquin 1977) and the registrant's study suggest that malathion persistence in anaerobic environments is short, however, due to the high pH in the registrant's study a quantitative assessment of the degradation and degradation products cannot be performed.

In the registrant submitted anaerobic aquatic metabolism study [2,3- ^{14}C]- and technical grade-malathion added to a sandy loam soil degraded with a registrant-calculated half-life of approximately 2.5 days in sediment (pH 7.8) and water (pH 8.7). This study provides useful information, but hydrolysis was probably the main route of degradation in the study since the pH of the system was in the basic range which favors hydrolysis. Although most of the residues remained in the water phase (less than 20% of the applied radioactivity was associated with the soil at any sampling interval), the degradation products were similar in both sediment and water phases. The degradation products at maximum concentrations in the water phase were the monocarboxylic acid of malathion (MCA, 28% at Day 4), demethyl monocarboxylic acid (21% at Day 7), dicarboxylic acid (21 % at Day 14) and the demethyl dicarboxylic acid metabolite (39% at Day 45). The degradation products at maximum concentrations in the sediment were the monocarboxylic acid of malathion (4.5% at 6 hours), demethyl monocarboxylic acid (8.1% at Day 45), and dicarboxylic acid (5.2% at Day 4). The EFED calculated half-life for malathion monocarboxylic acid was 11 days.

This study is considered satisfactory with supporting hydrolysis and open literature data suggesting that malathion is unlikely to persist in anaerobic aquatic conditions (MRID 42216301, 43166301). Repeated studies under acidic conditions may be requested if more quantitative data on malathion persistence in these environments are required.

Aerobic Aquatic Metabolism:

A USGS monitoring study (1998) shows detections of malathion in large rural and urban streams. Many open literature studies have been conducted on the fate and persistence of malathion in the aquatic environment. Reported degradation rates vary and are likely to be significantly increased by biodegradation and pH. Eichelberger and Lichtenberg (1971) found 75% and 90% degradation in river water in one and two weeks, respectively. Guerrant et al (1970) found malathion half lives in

pond, lake, river and other natural waters varied from 0.5 to 10 days and was dependent on pH. Other studies are summarized in Mulla *et al* (1981) and Howard (1991).

Registrant submitted studies were conducted under alkaline conditions which favor hydrolysis. Thus, degradation rate and products may not be representative of acidic aquatic conditions. In the registrant submitted aerobic aquatic metabolism study, a mixture of [2,3-¹⁴C]- and technical grade-malathion added to a sandy loam soil rapidly degraded in the aerobic aquatic environment with a half-lives of approximately 1.09 days in the water phase (pH 7.8) and 2.55 days in sediment (pH 8.5). As mentioned above, hydrolysis was probably the main route of degradation in the study since the pH of the system was in the basic range and hydrolysis occurs most rapidly at pH 9. Major degradates in water and soil were similar: mono- and dicarboxylic acids of malathion, demethyl monoacid and demethyl diacid, while in sediment no demethyl diacid was detected. The EFED calculated half-life for malathion monocarboxylic acid was 3 days.

This study is considered supplemental at this time (MRID 42271601, 43166301) as quantitative data for malathion degradation in acidic aquatic environments where it is likely to have longer persistence are required. Malathion's high toxicity to aquatic animals and the need to model malathion fate for drinking water assessments in a conservative manner are two important aspects of this assessment which directly rely upon quantitative aquatic fate data.

Mobility:

Leaching/adsorption/desorption:

The short soil persistence of malathion reduces the risk of leaching to groundwater however it has been detected in the groundwater of at least three states (USEPA 1992). Demethyl and carboxylic acid degradates are expected to be highly mobile particularly in alkaline soils.

Based on batch equilibrium (adsorption/desorption) studies, unaged [¹⁴C]malathion was determined to be very mobile in sandy loam, sand, loam, and silt loam soils, with respective Freundlich K_{ads} values of 0.83-2.47; and K_{oc} values from 151-183. Adsorption was correlated with organic carbon content. Values for $1/n$ for K_{ads} were clustered in the range of 0.904-0.978 (MRID 41345201).

Malaoxon was detected in any leachate or soil extracts in concentrations $\geq 0.12\%$ (≥ 6 ppb) of applied radioactivity. (MRID 43868601, 41345201, 43166301)

Laboratory volatility:

Three different malathion formulations [Ready To Use (RTU), Ultra Low Volume (ULV), Emulsifiable Concentrate (EC)] added to a silt loam soil did not undergo any appreciable volatilization, when

measured under different soil moisture regimes or air flow rates. No more than 5.1% of the applied radioactivity volatilized during the 16 days of the study.

Dissipation

Terrestrial field dissipation:

Open literature studies provide varying rates of terrestrial dissipation. Mulla *et al* (1981) summarizes degradation results from several field studies including: no residues after 6 months (Roberts *et al* 1962) and 85% degradation in 3 days and 97% in 8 days (Lichtenstein and Schulz 1964). The fastest route of terrestrial field dissipation is generally accepted to be via microbial degradation.

In the registrant submitted field dissipation study using a rate of 1.16 lb ai/A, malathion or malaoxon residues were detected at ≤ 10 ppb in the 0-6" layer in cotton/bareground sites in GA. Due to the sampling depth it is not possible to determine how much malathion remained at the soil surface relative to that which moved through the first six inches. Residues detected in the plots in the 6-12" layer after the 2nd, 3rd, 4th and 5th treatments averaged 35, 37, 5.6 and 9.4 ppb, respectively. Malathion was detected in the 12-18 inch soil depth at 16 ppb in one replicate soil sample; however, the detection was attributed to contamination. The detection of malathion below six inches along with the low K_d values reported for malathion make it feasible that leaching below 12 inches may have occurred in the field dissipation studies.

The half-life could not be determined due to the rapid dissipation of malathion, although it is probably <1 day (MRID 41748901, 43042401, 43166301).

In a field dissipation study located in California, malathion was applied at a maximum rate of 1.16 lb ai/A once a week for 6 weeks. The resulting dissipation half-life was <0.2 days. In certain instances, malathion was detected below the 12 inch soil depth (MRID 41727701, 43042402, 43166301).

Aquatic field dissipation:

Open literature references detailing persistence in aquatic environments are briefly mentioned under the aquatic metabolism section.

In the first registrant aquatic field dissipation study located in Missouri, malathion was applied at a maximum rate of 0.58 lb ai/A in three weekly applications to a flooded rice paddy (soil pH 6.1, water pH not stated). Malathion residues detected in water samples collected after the first and second application had dissipated below the detection limit (0.01 ppm) in samples taken prior to the second and third applications. In water samples collected one day after the last application, malathion concentrations averaged 0.017 ppm and had decreased to <0.01 ppm by the second sampling day. Malaoxon residues were <0.01 ppm at all sampling dates.

The data indicate a very rapid dissipation of malathion in water, probably <1 day; however, an accurate half-life could not be determined because of the rapid dissipation (MRID 42058402, 43166301) .

In the second aquatic field dissipation study performed in California (soil pH 7.4, water pH not stated), malathion was applied at a rate of 0.58 lb ai/A in three weekly applications to flooded plots. The resulting dissipation half-life could not be determined in the California plot because it was probable that only 1-2% of the intended amount of malathion was applied (MRID 42058401, 43166301).

Accumulation

Accumulation in irrigated crops:

Crop accumulation and residue studies are conducted under the purview of the Health Effects Division. In an accumulation in irrigated crops study located in Missouri, which used the irrigation water from the above mentioned aquatic field dissipation study on rice, malathion or malaoxon did not accumulate in corn, grain sorghum, soybeans or sweet potatoes. The study was unacceptable mainly because the authors did not attempt to determine residues in plants, other than malathion and malaoxon, which were detected in laboratory studies. (MRID 42058402, 43166301).

Accumulation in fish:

Aquatic bioconcentration values ranging from 7.36 (lake trout), 29.3 (coho salmon), 869 (white shrimp), to 959 (brown shrimp) are summarized in Howard (1991).

The registrant submitted study shows [¹⁴C]malathion residues did not significantly accumulate in bluegill sunfish exposed to 0.99 ppb [¹⁴C]malathion in a flow-through system for 28 days. Average concentrations of malathion were 3.9 to 18 ppb in the edible fish parts, 21 to 130 ppb for whole fish and 34 to 200 ppb in the nonedible tissue. [¹⁴C]malathion residue equivalents in the edible fish tissue during depuration ranged from 18 ppb at the start to 4.8 ppb by day 14. Whole fish concentrations decreased from 110 to 4.5 ppb and non-edible fish concentrations decreased from 150 to 5.8 ppb after day 14. Approximately 73, 96 and 96% of the radioactivity depurated from the edible, whole and nonedible portions of fish, respectively. The non-depurated radioactivity consisted of up to 22 other components present in concentrations <10% of total applied radioactivity and were not further identified.

The only significant residue detected in fish tissue was malathion monocarboxylic acid (MCA) in concentrations of 33.3-35.9% (44.8-61.2 ppb) of total radioactive residues (TRR). Up to 22 other components were present in levels of 0.1 to 5.7% (0.1 to 7.7 ppb) and included malathion dicarboxylic acid (MDCA), malaoxon, desmethyl malathion, monoethylfumarate and oxalacetic acid. Malaoxon was present in concentrations ≤2.7 ppb; while parent malathion was present in concentrations of 0.2 ppb.

Maximum BCFs, as a function of radioactive residues present, ranged from 4.2 to 18, 23 to 135, and 37 to 204 for edible, whole fish and nonedible, respectively (MRID 43106401, 43106402, 43340301).

Spray Drift

No registrant-submitted spray drift studies were reviewed. A study conducted for the Boll Weevil Eradication Program at Penn State (1993) examined malathion drift under conditions of boll weevil control (1 lb/A = 112 mg/m²) with an ultra-low volume (ULV) formulation. Deposition up to 21.0, 11.5, 2.9, and 0.7% of that applied was observed at 100, 200, 500, 1000 meters downwind. Due to the size of the particles generated, the ULV formulation is expected to produce the highest levels of drift.

To satisfy spray drift study requirements the registrant, in conjunction with other registrants, formed the Spray Drift Task Force (SDTF). The SDTF has completed and submitted to the Agency its series of studies which are intended to characterize spray droplet drift potential due to various factors, including application methods, application equipment, meteorological conditions, crop geometry, and droplet characteristics. During 2000 EPA plans to complete the evaluation of these studies. In the interim and for this assessment of malathion, the Agency is relying on previously submitted spray drift data and the open literature for off-target drift rates. The simplified rates used are 1% of the applied spray volume from ground applications and 5% from aerial and orchard airblast applications at 100 feet downwind. It is important to note that drift studies on ULV malathion show significantly higher levels of drift. After its review of the new studies, the Agency will determine whether a reassessment is warranted of the potential risks from the application of malathion to nontarget organisms.

The status of the environmental fate data requirements for malathion for terrestrial food crop, terrestrial feed crop, indoor non-food, and residential outdoor uses is summarized in the appendices.

C. Terrestrial Exposure Assessment

Terrestrial Vegetation Exposure

Exposure Concentrations for Nontarget Terrestrial Wildlife and Insects

For pesticides applied as a nongranular product (e.g., liquid, dust), the estimated environmental concentrations (EECs) on food items following product application are compared to LC50 values to assess risk. The predicted 0-day maximum and mean residues of a pesticide that may be expected to occur on selected avian or mammalian food items immediately following a direct single application at lb ai/A are tabulated below.

Table 4

Estimated Environmental Concentrations on Avian and Mammalian Food Items (ppm) Following a Single Application at 1 lb ai/A)

Food Items	EEC (ppm) Predicted Maximum Residue ¹	EEC (ppm) Predicted Mean Residue ¹
Short grass	240	85
Tall grass	110	36
Broadleaf/forage plants, and small insects	135	45
Fruits, pods, seeds, and large insects	15	7

¹ Predicted maximum and mean residues are for a 1 lb ai/a application rate and are based on Hoerger and Kenaga (1972) as modified by Fletcher *et al.* (1994).

Residues on Vegetation from Multiple Applications

Predicted residues (EECs) resulting from multiple applications are calculated in various ways. The Agency has employed simple first order dissipation calculations to predict concentrations on vegetative surfaces following spray application at 0.18 to 6.25 lbs ai/acre. The application scenarios are based on maximum tested rates, minimum intervals and maximum numbers of applications tested for establishment of residue tolerances on food. An assumed 90th percentile foliar dissipation half-life of 5.5 days on plant surfaces was derived from averaging of calculated half lives based on 37 reports of malathion residue samples collected on 12 different crops by various researchers from 1957 to 1981 as reported in Willis and McDowell, 1987 (see table below).

Table 5 a . Foliar Halflife Estimates-Willis and McDowell

Crop(# samples) Formulation types	Location	Rainfall in mm	Half-life in days
Alfalfa(3) Dust & EC	NC, MA	6.1 to 17.8	0.7, 2.0, and 4.1
Apple(1)	WA	Not reported	3.2 ± 1.2
Chicory(3) Dust, EC, & WP	MD	0	0.7, 0.8, and 1.4
Collards(4) Dust, WP, & EC	NC, MD	0	1.0, 1.4, 1.5, and 1.7
Cotton(5) EC	KY, MS	Not reported	0.3, 0.4, 1.1, 0.6, 6.1
Citrus(1)	FL	Not reported	2.3
Endive(3) Dust, WP, & EC	MD	48.8	1.2, 1.5, 5.9
Leaf lettuce(3) Dust, WP, & EC MD		0	2.9, 5.8, 6.8
Lima Beans(3) ULV, oil mix	MD	Not reported	1.3, 2.5, 2.8

Crop(# samples) Formulation types	Location	Rainfall in mm	Half-life in days
Kale(1) EC	DC	Not reported	3.1
Turnip(1) EC	FL	60.7	6.4 ± 2.7
Tobacco(8) Dust, WP, & EC	MD	0.8 to 16.0	0.7, 0.7, 1.7, 2.1, 2.4, 2.8, 3.2, 10.9

Based on this foliar dissipation data and resulting residue calculations a table has been developed with food tolerance scenarios as guidance in predicting maximum expected surface residue ranges for terrestrial vegetation and insects.

Table 5bMalathion Crop Use Terrestrial EEC Range Estimates in ppm-Grasses and Seeds
Cheminova and IR4 Supported Maximum Tolerance Rates

	Foliar Dissipation T1/2=5.5 Days												
	Number of Applications												
	Rate lb ai/A	Int. Day	1 grass- seed	2	3	4	5	6	7	8	9	10	12-25
A	0.175	7D	42-1.2									72-4.5	
B	0.50	NA	120-3.5										
C	0.61	5D	146-4.3				300-19						
C	0.61	7D	146-4.3	189-9	232-14								
C	0.61	14D	146-4.3	171-11									
D	0.76	10D	182-5.3				254-16						
E	0.94	3D	226-7										
E	0.94	6D	226-7					420-26					
E	0.94	7D	226-7		357-22				384-24				
F	1.0	7D	240-7					407-25					
G	1.25	3D	300-8.8	505-32				854-53					

G	1.25	5D	300-8.8				614-38						
G	1.25	7D	300-8.8		475-30	490-31	505-32	509-32	510-32	511-32	511-32	512-32	512-32
G	1.25	14D	300-8.8	351-22									
H	1.50	7D	360-10		571-36			611-38					
I	1.56	7D	374-11	425-16			631-39						
J	1.88	5D	451-13					943-59					
J	1.88	7D	451-13		715-45	747-47		766-48					
J	1.88	14D	451-13	528-33									
K	2.03	6D	487-14					908-57					
K	2.03	7D	487-14		772-48	806-50							
L	2.5	3D	600-18		1292-56								1905-119
L	2.5	5D	600-18		1121-68								
L	2.5	7D	600-18		951-59		1011-63						
M	3.43	5D	823-24										
N	3.75	7D	900-26			1490-61		1527-96					
N	3.75	14D	900-26										
O	4.7	30D	1128-33	1153-40									
P	5.0	7D	1200-35	1696-52	1902-69	1987-87							
Q	6.25	30D	1500-44		1535-46								

Scenario to Crop Relation for Table 5b

0.175 lb ai/A A10=Orange, Grapefruit, Lemon, Lime, Tangerine, Tangelo, and Kumquat

0.50 lb ai/A B1=Flax

0.61 lb ai/A C5(5D)=Sweet Corn , C2(7D)=Hops, C3(7D)=Beans, Corn, Rice, Sorghum, Wheat, and Rye

	C2(14D) =Alfalfa, Clover, Lespedeza, Lupine and Vetch
0.76 lb ai/A	D5 =Blueberry
0.94 lb ai/A	E1(3D) =Grass for hay, E4(3D) =Mushroom, E6(6D) =Strawberry, E3(7D) =Peppermint and spearmint, E7(7D) =Macadamia
1.0 lb ai/A	F6(7D) =Melons, Watermelon, Pumpkin and Winter Squash
1.25 lb ai/A	G1(3D) =Grass for hay, G2(3D) =Field corn , G2(7D) Brussel sprouts, cauliflower, collards, kale, kohlrabi G6(3D) =Mustards, G25(3D) =Cotton, G5(5D) =Watercress, G3(7D) =Rice, Sorghum, Wheat, Rye, Barley, Oats and Corn, G4(7D) =Blueberry(ULV), G5(7D) =Turnip, Broccoli, Apple, Sweet Corn, Beet, Horseradish, Parsnip, Radish, Rutabaga, Salsify G6(7D) = Cabbage and Cherry(ULV), G7(7D) =Carrot , G8(7D) =Mango and Passion fruit , G9(7D) =Asparagus G10(7D) =Pears and Quince , G12(7D) =Guava and Papaya, G2(14D) =Alfalfa, Clover, Lupine, Vetch and Lespedenza
1.5 lbs ai/A	H2(7D) =Celery, H6(7D) =Okra
1.56lbs ai/A	I2(7D) =Potato, Sweet potato, I5(7D) =Onion, Garlic, Shallot, Leeks
1.88 lb ai/A	J6(5D) =Lettuce, J4(7D) =Blackberry, Raspberry, Loganberry, Boysenberry, Dewberry, Currant, Gooseberry, J3(7D) =Cucumber, Chayote, J6(7D) = Strawberry, J2(14D) =Grapes
2.03 lbs ai/A	K6(6D) =Strawberry(50% WP), K3(7D) = Spinach, Dandelion, Endive, Parsley and Swiss Chard, K4(7D) =Blackberry, Raspberry, Gooseberry, Loganberry, Dewberry, Currant and Boysenberry
2.50 lb ai/A	L25(3D) =Cotton, L3(5D) =Figs, L3(7D) =Mustards, Walnuts, and Pecans, L5(7D) =Peas
3.43 lb ai/A	M5(5D) =Tomato, Pepper, Eggplant
3.75 lb ai/A	N4(7D) =Apricots, N6(7D) =Cherry, N4(14D) =Peach and Nectarine
4.7 lb ai/A	O2(30D) =Avocado
5.0 lb ai/A	P3(7D) =Pineapple, P4(7D) =Chestnuts
6.25 lb ai/A	Q3(30D) =Oranges, Grapefruit, Lemon, Lime, Tangerine and Tangelo

No Use Rate Recommended As of December 1997: Broccoli Raab, Chinese cabbage, Cranberry, Dates (Gowan Co. only), and Hops(not clarified).

The estimates of residues in the above table are not highly conservative as calculated foliar dissipation half lives were as high as 10.9 days in the Willis and McDowell report. A slight increase in residues is predicted from multiple applications.

Johansen *et al* (1965) conducted a study entitled Bee Poisoning Hazard of Undiluted Malathion Applied to Alfalfa in Bloom. Foliar residues were measured during this study, which is also referenced in the hazard portion of this document under non-target insect toxicity field studies. As can be seen the malathion residues appeared relatively stable on surfaces of alfalfa foliage for the first 4 days. It appears that washoff may have led to significant reduction of residues on vegetative surfaces. Degradation appeared marginal before the rainfall events.

Table 6. Malathion Residues on Alfalfa from Johansen <i>et al</i> (1965)			
Days Post Application	Measured Residues Control Plots in PPM	Measured Residues Treated Plots in PPM	Precipitation in inches
0		28.8	0
1		18.9-21.1	0
2		23.8	0
3		27.6	0
4	<0.1	28.2	0.02
5		8.2	0.26

6		2.3	0.01
7		4.5	0
14	<0.1	0.4	0
21	<0.1	<0.1	0

Awad et al (1967) conducted a study entitled The Effect of Environmental & Biological Factors on Persistence of Malathion Applied as Ultra Low Volume or Emulsifiable Concentrate to Cotton Plants. In the study small amounts of insecticide were applied to plant surfaces and glass plates. Samples were taken at application and 1, 3, 6 & 9 days post application. Malathion EC and ULV formulations were used. Residues were obtained by washing leaves or plates with 100 ml of distilled water. EC formulations appeared to penetrate leaf tissues more rapidly than ULV formulations. Lack of absorption led to higher residue levels on glass plate surfaces. Calculated foliar half lives were ULV $T_{1/2} = 5.5$ days and EC $T_{1/2} = 23$ days.

D. Water Resource Assessment

The highest level of malathion surface water contamination occurs in urban areas. Malathion deposited on anthropogenic surfaces decays slowly and is more likely to be washed off to adjacent water bodies. Agricultural uses of malathion are most likely to contaminate surface water through off-target drift. This is particularly true with aerially-applied, drift-prone ULV formulations.

Malathion contamination of ground water has been observed at higher levels than predicted by modeling. Malathion ground water contamination is surprising given its rapid degradation under most conditions and emphasizes the need for data requested on malathion fate under conditions which do not favor degradation.

EFED uses a tiered system to generate estimates of pesticides in surface and groundwater. First tier assessments utilize the simple farm pond model GENEEC and reviewed monitoring studies. Second tier assessments are intended to reduce the uncertainties of first tier assessments and produce more realistic estimates of pesticide concentrations. Second tier assessments utilize PRZM-EXAMS modeling and a more comprehensive review of available monitoring data.

Water assessments used in this document examine both malathion and when possible its toxic degradate malaoxon. Technical malathion contains, in addition to malaoxon, other impurities that are demonstrated to be toxic or to synergize malathion toxicity. These chemicals include isomalathion and alkyl phosphorothioates and -dithioates. These impurities are normally present individually at levels less than 1% but can increase under improper storage conditions. As EFED possesses very little environmental fate data on these impurities it is not possible to assess their fate or persistence in the environment through modeling. Therefore an assessment of malathion impurities in water is not included in this document.

1. Drinking Water

A first tier drinking water assessment has been performed to provide the Health Effects Division with a conservative estimate of malathion and malaoxon in drinking water. Acute and chronic drinking water concentrations were estimated with proposed pesticide use patterns that produced the highest aqueous pesticide levels. The model results reflect first tier drinking water concentration estimates and environmental concentrations as a result of agricultural use. HED has indicated that malathion's degradate, malaoxon, is to be included in the tolerance expression for malathion. Thus, water concentrations are provided in this assessment for both malathion and, when possible, malaoxon. The results are summarized in the table below. A more detailed discussion is provided in the discussion on ground water and the memo sent to HED is included in the appendices.

Table 7. Tier I drinking water concentrations for malathion and malaoxon.

compound / exposure type	surface water		ground water	
	estimated concentration (ppb)	source of concentration	estimated concentration (ppb)	source of concentration
malathion / acute	226	GENEEC peak	3.1	Monitoring data
malathion / chronic	21.2	GENEEC 56-day ave.		
malaoxon / acute	96.0	GENEEC peak	3.1	Derived from malathion monitoring data
malaoxon / chronic	75.5	GENEEC 56-day ave.		

EFED recommends that 226 and 96.0 ppb (Table 7) be considered as the highly conservative first tier estimates for acute surface drinking water levels for malathion and malaoxon, respectively. For chronic surface drinking water levels, 21.2 and 75.5 ppb are recommended for malathion and malaoxon, respectively. The chronic malaoxon value exceeds the chronic malathion level because of its longer expected environmental persistence.

First tier groundwater concentrations were derived from monitoring data because they were higher than results from the SCIGROW model (0.142 ppb for cotton). The highest detected malathion concentration in groundwater accepted by EFED was 3.1 ppb. Malaoxon was not examined in this monitoring study, but the same value is expected to be a conservative estimate of malaoxon concentration as malaoxon production usually accounts for less than 10% of malathion degradates. EFED recommends exposure estimates of 3.1 ppb for malathion and 3.1 ppb for malaoxon in ground water.

Standard modeling techniques were modified to estimate malaoxon concentrations. Malaoxon levels were estimated with the GENEEC model with the assumption that fate variables which were not known are the same as those for malathion. Acceptable environmental fate studies specifically for malaoxon; including degradation, metabolism, mobility, dissipation, and solubility data; are needed for complete assessment.

EFED notes that there is limited information available on the conversion of malathion to malaoxon during drinking water treatment. Available data suggest that conversion of malathion to malaoxon may be more efficient during water treatment than under natural conditions in the field, thus malaoxon may be present at a much higher concentration relative to malathion after water processing.

In a limited sampling of water entering and leaving a water treatment plant in Florida both malathion and malaoxon levels generally decreased after treatment, however, one sample showed an increase in malaoxon (USDA 1997). Data from a more detailed sampling and analysis with a lower detection limit show a much higher rate of conversion (personal communication, Dr. Marion Fuller, Florida Department of Agriculture and Consumer Services).

Data supplied by the Florida Department of Agriculture and Consumer Services Bureau of Pesticides provides malathion concentrations entering and leaving the Hillsborough Water Treatment Plant during the period of July 16 - August 27 1997. At this time the area was being sprayed with baited malathion for medfly control. The reservoirs and other known sources of drinking water reportedly did not receive direct insecticide treatment. Samples were collected at a boat dock prior to entering the plant and as well as after treatment. Table 8 summarizes the data.

Table 8. Drinking water entering and leaving the Hillsborough Water Treatment Plant 1997. Detection limits were 0.1 ppb for both malathion and malaoxon.

Malathion-malaoxon conversion in water treatment						
location	malathion (average of detected concentrations, ppb) ¹	s.d.. dev.	n	malaoxon (average of detected concentrations, ppb) ¹	s.d.. dev.	n
Boat dock	1.00	0.90	13	nd	-	25
Lab/Finished	nd	-	25	1.09	0.73	14

These results suggest that the water treatment process can result in a very efficient conversion of malathion to its oxon. It is likely that the efficiency would vary depending on the type of water treatment process used in sterilization. The stability of malaoxon in the drinking water supply cannot be assessed as EFED does not presently possess hydrolysis data on malaoxon. Therefore it is assumed to be stable in drinking water.

2. Estimated Concentrations for Surface Water Resources

Tier I Assessment

Summary

Based on fate characteristics, model predictions and actual monitoring studies, the Agency predicts malathion will reach surface and groundwater water from the proposed reregistration uses. Surface water concentrations resulting from agriculture uses were modeled using the GENEEC screening model. Results are presented in the following table.

Table 9. GENEEC Predicted Environmental Concentrations For Aquatic Exposure

Estimated Aquatic EECs in PPBs: Peak (top), 21 day mean (middle), and 56 day mean (bottom).

	Number of Applications												
	Rate lb ai/A	Int. Day	1	2	3	4	5	6	7	8	9	10	12-25
A	0.175	7D										8.24 2.03 0.78	
B	0.50	NA	11.4 2.8 1.07										
C	0.61	7D		23.2 5.7 2.2	27.7 6.8 2.6								
C	0.61	14D		26.8 6.6 2.53									
D	0.76	10D					40.6 10 3.4						
E	0.94	3D	21.7 10.4 2.05										
E	0.94	6D						45.4 11.2 4.24					
E	0.94	7D			42.2 10.4 3.94				42.5 10.5 3.97				
F	1.0	7D						45.2 11.2 4.22					
G	1.25	3D	28.5 7.0 2.66	54.3 13.4 5.07				90.4 22.3 8.5					
G	1.25	5D					66 16.3 6.16						
G	1.25	7D			56.1 13.8 5.24	56.5 13.9 5.3	56.5 13.9 5.28	57.2 14.1 5.4	56.5 13.9 5.28	56.6 13.9 5.28	56.6 13.9 5.28	56.6 13.9 5.28	56.6 13.9 5.28
G	1.25	14D		47.1 11.6 4.53									

H	1.50	7D			67.3 16.6 6.28			67.3 16.6 6.28					
	Rate lb ai/A	Int. Day	1	2	3	4	5	6	7	8	9	10	12-25
I	1.56	7D		67.8 16.7 6.33			70.8 17.5 6.61						
J	1.88	5D						99.4 24.6 9.28					
J	1.88	7D			84.4 20.8 7.87	84.9 21 7.92		85 21 7.94					
J	1.88	14D		70.8 17.5 6.61									
K	2.03	6D						98.1 24.2 9.16					
K	2.03	7D			91.1 22.5 8.5	91.7 22.6 8.6							
L	2.5	3D											181
L	2.5	5D			128 31.6 12								
L	2.5	7D			112 27.7 10.5		113 27.9 10.6						
M	3.43	5D					81 20 16.9						
N	3.75	7D				169 41.7 15.8		169 41.7 15.8					
N	3.75	14D				142 35 13.2							
O	4.7	30D		171 42.2 15.9									
P	5.0	7D			224 55.3 20.9	225 55.6 21.1							

Q	6.25	Q1			226								
					55.8								
					21.2								

Table 9 Crop Scenario Relationships

0.175 lb ai/A	A10= Orange, Grapefruit, Lemon, Lime, Tangerine, Tangelo, and Kumquat
0.50 lb ai/A	B1= Flax
0.61 lb ai/A	C5(5D)= Sweet Corn , C2(7D)= Hops, C3(7D)= Beans, Corn, Rice, Sorghum, Wheat, and Rye C2(14D)= Alfalfa, Clover, Lespedeza, Lupine and Vetch
0.76 lb ai/A	D5= Blueberry
0.94 lb ai/A	E1(3D)= Grass for hay, E4(3D)= Mushroom, E6(6D)= Strawberry, E3(7D) = Peppermint and spearmint, E7(7D)= Macadamia
1.0 lb ai/A	F6(7D)= Melons, Watermelon, Pumpkin and Winter Squash
1.25 lb ai/A	G1(3D)= Grass for hay, G2(3D)= Field corn , G2(7D) = Brussel sprouts, cauliflower, collards, kale, kohlrabi G6(3D)= Mustards, G25(3D)= Cotton, G5(5D)= Watercress, G3(7D)= Rice, Sorghum, Wheat, Rye, Barley, Oats and Corn, G4(7D)= Blueberry(ULV), G5(7D)= Turnip, Broccoli, Apple, Sweet Corn, Beet, Horseradish, Parsnip, Radish, Rutabaga, Salsify, Sweet potato , G6(7D)= Cabbage and Cherry(ULV), G7(7D)= Carrot , G8(7D)= Mango and Passion fruit , G9(7D)= Asparagus G10(7D)= Pears and Quince , G12(7D)= Guava and Papaya, G2(14D)= Alfalfa, Clover, Lupine, Vetch and Lespedenza
1.5 lbs ai/A	H2(7D)= Celery, H6(7D)= Okra
1.56lbs ai/A	I2(7D)= Potato, Sweet potato, I5(7D)= Onion, Garlic, Shallot, Leeks
1.88 lb ai/A	J6(5D)= Lettuce, J4(7D)= Blackberry, Raspberry, Loganberry, Boysenberry, Dewberry, Currant, Gooseberry, J3(7D)= Cucumber, Chayote, J6(7D)= Strawberry, J2(14D)= Grapes
2.03 lbs ai/A	K6(6D)= Strawberry(50% WP), K3(7D)= Spinach, Dandelion, Endive, Parsley and Swiss Chard, K4(7D)= Blackberry, Raspberry, Gooseberry, Loganberry, Dewberry, Currant and Boysenberry
2.50 lb ai/A	L25(3D)= Cotton, L3(5D)= Figs, L3(7D)= Mustards, Walnuts, and Pecans, L5(7D)= Peas
3.43 lb ai/A	M5(5D)= Tomato, Pepper, Eggplant
3.75 lb ai/A	N4(7D)= Apricots, N6(7D)= Cherry, N4(14D)= Peach and Nectarine
4.7 lb ai/A	O2(30D)= Avocado
5.0 lb ai/A	P3(7D)= Pineapple, P4(7D)= Chestnuts
6.25 lb ai/A	Q3(30D)= Oranges, Grapefruit, Lemon, Lime, Tangerine and Tangelo

Tier II Assessment

Summary

Since the EEC's derived from first-tier GENEEC simulations were above levels of concern (LOCs) for aquatic organisms, Tier II EEC's were calculated. The second tier assessment for malathion in surface waters utilized PRZM-EXAMS modeling and the review of available monitoring data. It is not possible to perform second tier modeling of malaoxon due to the lack of fate data on this toxic degradate. Required data for malaoxon include degradation (161-1), metabolism (162-1,4), and mobility (163-1,2) and well as data on solubility and rates of formation under suitable conditions.

PRZM 3.1 was used to simulate the agricultural field, and EXAMS 2.97.5 was used to simulate fate and transport in surface water. Each model scenario simulates a single site which represents the use of malathion on a particular crop. The weather and agricultural practices were simulated over multiple years, in this case 24 to 36, so the probability of an EEC occurring at that site can be estimated.

Five application scenarios were simulated, using crops which together represent more than 50% of malathion use in the United States as well as the highest use-rates proposed by the registrant. The EECs derived from these simulations were generally lower than those generated by Tier I GENEEC runs (see Table 10). Twenty-two additional crops have malathion application rates, numbers of applications and application intervals identical to one of the five crops simulated (see Table 1). The EECs generated from the five scenarios may be used as surrogates for these twenty-two crops, recognizing that these predicted EECs may vary due to geographical and other differences.

Monitoring and field studies were also examined in this second tier assessment. Studies reviewed include those associated with Mediterranean fruit fly and boll weevil eradication programs. Data from these studies (summarized in tables 10-13) shows in agricultural settings that the most important source of aquatic malathion is off-target drift and malaoxon is only detected at low concentrations. In urban areas, runoff is more important and malaoxon levels can be much higher.

PRZM-EXAMS Modeling

PRZM-EXAMS estimates aquatic concentrations in a one hectare pond that is two meters deep next to a ten hectare plot. The pond receives both simulated drift and runoff from the field. PRZM models terrestrial pesticide fate and transport and EXAMS models the aquatic portion.

The Pesticide Root Zone Model (PRZM) is a one-dimensional, dynamic, compartmental model that can be used to simulate chemical movement in unsaturated soil systems within and immediately below the plant root zone. It has two major components-- hydrology (and hydraulics) and chemical transport. The hydrologic component for calculating runoff and erosion is based on the Soil Conservation Service curve number technique and the Universal Soil Loss Equation.

Evapotranspiration is estimated either directly from pan evaporation data, or based on an empirical formula. Evapotranspiration is divided among evaporation from crop interception, evaporation from soil, and transpiration by the crop. Water movement is simulated by the use of generalized soil parameters, including field capacity, wilting point, and saturation water content.

Exposure Analysis Modeling System (EXAMS II) is a model that can receive progressive PRZM runoff concentration output to further predict aquatic pesticide concentrations in a simulated pond. The predicted concentrations over the period of time (usually 24-36 years) can be averaged over time to produce peak and time averaged concentrations which take into account aquatic degradation.

EFED has prepared standard PRZM input files for the five crops simulated. The locations used to build these scenarios were chosen to represent areas of greatest malathion use. EFED has prepared draft summary documents which describe the input parameters used to develop the standard scenarios. Once these documents have been finalized, they can be provided upon request.

The five input files were adapted to simulate the application of malathion for the respective crops and states represented in the standard scenarios. Chemical-specific input for malathion was derived to the greatest extent possible from the environmental fate database submitted to the EPA by registrant

Cheminova. Application rates, numbers of applications, and application intervals simulated were consistent with the maximum values requested by the registrants for establishing tolerances. Average application rates and numbers of applications were taken from BEAD Quantitative Use Analysis reports. Planting and harvest dates, and likely dates of malathion application, were chosen based on conversations with academic and extension crop specialists, or USDA references. Further details on crop and chemical specific inputs are presented in the appendices.

Results

The PRZM-EXAMS Tier II EECs for malathion are listed along with GENEEC Tier I EECs in the following table for comparison purposes.

Table 10. Summary of model results inputting maximal and typical use rates for crops with high malathion usage and high use rates. Intervals and the total number of applications used for these modeling runs were chosen to be conservative. By using maximum use rates (used in food residue tolerance limits), minimal intervals between applications, and the maximum number of applications the modeled use scenarios are expected to reflect a high exposure scenario.

PRZM-EXAMS results								
Crop	% of total a.i. applied / year ¹	Use rate (lbs a.i./A)	Interval (days)	No. of applications	Model Comparisons			
					GENEEC		PRZM-EXAMS	
					peak	56 d ave.	peak ²	60 d ave. ³
Cotton	41.6%	Max: 2.5	3	25	181	16.9	291	47.7
		Typ: 0.3	[3] ⁴	4	20.6	1.95	7.9	0.50
Sorghum	7.4%	Max: 1.25	7	3	56.1	5.24	26.7	1.95
		Typ: 0.8	[7]	1	18.5	1.74	2.94	0.18
Apple	2.14%	Max: 1.25	7	5	56.5	5.28	0.80	0.19
		Typ: 0.7	[7]	3	31.4	2.93	0.59	0.09
Citrus	0.49%	Max: 6.25	30	3	226	21.2	156	10.7
		Typ ⁵ : 2.5	[30]	1	57.1	5.33	42.6	2.33
Lettuce	0.45%	Max: 1.88	5	6	99.4	9.28	15.4	2.98
		Typ: 2.0	[5]	1	45.7	4.26	5.63	0.56

¹Pesticide data compiled by the National center for Food and Agricultural Policy for 1991-1993 and 1995.

² Peak concentration expected once in ten years.

³ The 60 day average value expected once in ten years.

⁴ Since data on typical intervals is not available the minimum interval was used in model runs with average use rates and number of applications.

⁵ Typical values for oranges.

Limitations of Modeling Analysis

There are several factors which limit the accuracy and precision of this analysis including the selection of the high exposure scenarios, the quality of the input data, the ability of the models to represent the real world, and the number of years that were modeled.

Scenarios that are selected for use in Tier 2 EEC calculations are ones that are likely to produce large concentrations in the aquatic environment. It should represent a site that really exists and would be likely to have the pesticide in question applied to it. It should be extreme enough to provide conservative estimates of the EEC, but not so extreme that the model cannot properly simulate the fate and transport processes at the site. Currently, sites are chosen by best professional judgement to represent sites which generally produce EEC's larger than 90% of all site use for that crop. The EEC's in this analysis are accurate only to the extent that the site represents this hypothetical high exposure site. The most limiting part of the site selection is the use of the standard pond with no outlet. Obviously, a Mississippi pond, even with appropriately modified temperature data is not the most appropriate water body for use in all situations. Some water bodies would likely have higher concentrations. These would be shallow water bodies near agricultural fields that receive most of their water as runoff from agricultural fields.

The quality of the analysis is directly related to the quality of the input parameters. Most of the fate data for malathion is complete, however, there is little fate and transport data on toxic impurities and degradates such as malaoxon. In addition, the aquatic persistence inputs were derived from studies conducted under alkaline conditions which would be likely to increase degradation rates and reduce the conservatism of this analysis.

The models themselves represent a limitation on the analysis quality. While the models are some of the best environmental fate estimation tools available, they have significant limitations in their ability to represent some processes. Spray drift is estimated as a straight 5% of the application rate reaching the pond for each application from ground application. In actuality, this value should vary with each application from near zero to higher than 20%. A second major limitation of the models is the lack of validation at the field level for pesticide runoff. While several of the algorithms (volume of runoff water, eroded sediment mass) are well validated and well understood, no adequate validation has yet been made of PRZM 3.1 for the amount of pesticide transported in runoff events. Other limitations of the models used are the inability to handle within site variation (spatial variability), lack of crop growth algorithms, and an overly simple soil water transport algorithm (the "tipping bucket" method). Another limitation is that only thirty-six years of weather data was available for the analysis at most sites and le:

at others. Consequently, at best there is approximately 1 chance in 20 that the true 10% exceedence EEC's are larger than the maximum EEC in the calculated in the analysis. If the number of years of weather data could be increased it would increase the confidence that the estimated value for the 10% exceedence EEC was close to the true value.

There are certain limitations imposed when Tier II EEC's are used for drinking water exposure estimates. Obviously, a single 10 hectare field with a 1 hectare pond does not accurately reflect the dynamics in a watershed large enough to support a drinking water facility. A basin of this size would certainly not be planted completely to a single crop nor be completely treated with a particular pesticide. Additionally, treatment with the pesticide would likely occur over several days or weeks, rather than all on a single day. This would reduce the magnitude of the concentration peaks, but also make them broader, reducing the acute exposure but perhaps increasing the chronic exposure. The fact that the simulated pond has no outlet is also a limitation as water bodies in this size range would have at least some flow through (rivers) or turnover (reservoirs). Also, irrigation of crops in the desert scenarios was not considered in the models. EEC's would likely be higher if EFED had irrigation data available. In spite of these limitations, a Tier II EEC can provide a reasonable upper bound estimate of the concentration found in drinking water. Risk assessment using Tier II values can be used as refined screens to demonstrate that the risk is below the level of concern.

Monitoring Data

Monitoring data was collected through two USDA programs: the Boll Weevil Eradication Program and the Mediterranean fruitfly (medfly) control effort.

Agricultural

Agricultural runoff monitoring data and field studies are consistent with aerobic soil metabolism studies showing that malathion is normally rapidly degraded on soil to compounds of lower toxicity.

Malathion is water soluble and thus poses the potential to be dissolved in rain water and transported in runoff water from application sites if it not degraded. Levels of malathion in runoff water have been examined mostly using automatic runoff sampling equipment (ARSEs) which consist of collection bottles with funnels recessed in the ground at sites where runoff is expected. The amount of malathion in runoff is expected to be affected by numerous variables including the soil type, half-life on the particular soil, the amount of time between application and precipitation, the amount of precipitation, and vegetation. Table 11 shows runoff monitoring data from five treated cotton fields in the Boll Weevil program close to bodies of water. Sampling was performed close to the field (10-25 feet) and closer to the water (40-135 feet from the field). In most cases, malathion concentrations were lower when the interval between application and rainfall was longer and/or distance from the field was farther. These observations are expected since increasing the interval allows for more degradation to occur and farther runoff travel distances allow malathion to penetrate soil and adsorb to soil particles before reaching shorelines.

Table 11. Field monitored runoff Cotton Bollweevil Control Program

Malathion levels were measured in runoff water from cotton fields after rain events. Two sets of measurements were made, one closer to the field and one farther from the field. Adapted from Environmental Monitoring Report: 1997 Southeast Boll Weevil Eradication Program Sensitive Sites at Environmental Monitoring Report: 1996 Southeast Boll Weevil Eradication Program.

Field Runoff			
field no. / sample distance from field	malathion conc (ppb)		time from application to rain (days)
	closer to field	farther from field	
1806-502 / near to field: 20' farther from field: 110'	9.3	1.9	1
	7.5	3.5	3
	>0.3	>0.3	6
1806-504 / near to field: 20' farther from field: 40'	70	33	1
	0.48	nd	6
2025-187 / near to field: 10' farther from field: 70'	0.42	0.53	2
2027-468 / near to field: 15' farther from field: 135'	63	nd	1
	nd	-	5
2100-200 / near to field: 25' farther from field: 50'	4.2	3.8	18
502 / near to field: 20' farther from field: 110'	1.1	nd	3
	0.5	nd	7
504 / near to field: 20' farther from field: 40'	10.9	nd	1
	41.8	15.6	3
	146	93.5	7
7806 / near to field: 0' farther from field: 45'	0.9	0.5	?
	1.7	1.1	6
	<0.3	0.3	14
325 / near to field: 15' farther from field: 60'	8.54	.82	2
	35.8	16.2	9

nd = none detected.

In monitoring projects the stability of malathion in still water has been examined. A half-acre pond surrounded by cotton fields with a 25 foot buffer was monitored for malathion (USDA BWEP 1993). Pesticide drift was determined to be the most important mechanism of contamination of the pond. Residues levels in the pond were lower before treatment (<0.1-0.44 ppb) and higher immediately after malathion application (<0.33-91.4 ppb). In most cases malathion in the pond degraded to <0.33 ppb within 7 days. Runoff was only a minor contributor of residue to the pond but only two rainfalls occurred during the sampling period. The malathion in the runoff samples collected were 9.75 and 76.1 ppb one day after the first and last treatments, respectively. Other natural bodies of water within treatment areas, but not intentionally receiving direct spray, showed no detectable levels of malathion 27 days after applications ceased (USDA BWEP 1995).

Tables 12 a,b,c. Spray drift to adjacent moving water. Malathion levels in moving water adjacent to cotton fields was measured before and after treatment. Measurements were made downstream from the field every 15 min from one hour before until 2-3.25 hours after application. Application was made when wind was not blowing directly over the water.

Spray Drift Southeast Boll Weevil Eradication Program							
site/comments	applicati on (aerial / ground)	treatmen t #	days since last treatmen t	time (min) / downstream malathion (ppb)			
				before treatment	time	after treatment	time
McCall's Creek: The creek was separated from the field (13.3 acre) by a continuous 600-700' buffer of 30-60' trees.	a	1	?	nd		nd	
	a	2	8	nd		nd	
	a	3	6	nd		nd	
	a	4	7	nd		nd	
	a	5	7	16.1	-60	nd	
North River: The field (8.3 acre) is separated from the river by a continuous buffer of mature hardwoods and moderately dense understory approximately 125' deep.	g	1	?	-		nd	
	g	2	5	nd		nd	
	g	3	7	nd		nd	
	g	4	6	<0.33	-45	<0.33	45
	g	5	6	<0.33	0	<0.33	0-120
	a	6	10	1.54	-45	1.44	60
	a	7	6	<0.33	0	<0.33	0-120
	a	8	7	1.77	-60	1.46	0
	a	9	10	0.42	-45	0.55	45

<p>Pursley Creek:</p> <p>The field (95.3 acre) was separated from the creek by 100' of mature hardwoods with a dense understory.</p>	a	1	?	nd		3.54	135
	a	2	7	nd		0.39	120
	a	3	7	nd		1.03	30
	a	4	7	nd		<0.33	75-120
	a	5	7	6.63	-30	3.80	120
	a	6	6	nd		3.35	150
<p>Stewart Creek:</p> <p>The field (19.2 acre) was separated from the creek by a 25' buffer of low -lying kudzu vegetation.</p>	g	1	?	nd		nd	
	g	2	8	<0.33	-60	nd	
	a	3	7	nd		7.69	60
	a	4	5	nd		3.16	75
	g	5	7	0.52		<0.33	0-240
	g	6	4	0.51		10.89	15
	g	7	5	<0.33		<0.33	15, 105, 135-250
	a	8	6	1.01		4.52	60
	a	9	12	<0.33		3.49	105

b.)

<p>Spray Drift</p> <p>Environmental Monitoring Report</p> <p>Boll Weevil Cooperative Eradication Program: 1995</p> <p>Texas Lower Rio Grande Valley</p>						
			downstream malathion (ppb) / time (min)			
site/comments	aerial/ ground	treatme nt #	before treatment	time	after treatment	time
#204060311/ Canal 200' from treated field.	?	1	0.324	-15	0.297	15
	?	2	4.89	-15	7.26	30
#2144070704 Canal 40' from treated field	?	1	6.38	-30	11.4	0
	?	2	2.27	-45	1.87	0
#212080704/ Canal 150' from treated field	?	1	4.81	-45	4.15	30,120
	?	2	2.4	-30	4.37	120
	?	3	5.92	-45	4.21	0

c.)

Spray Drift Environmental Monitoring Report Southern Rolling Plains Boll Weevil Eradication Program - 1994-1995						
			peak downstream malathion (ppb) / time (min)			
site/comments	method of app.	treatment #	before treatment	time	after treatment	time
Concho County stream (10303-1408) Samples collected 0.25 miles downstream	Hi-Boy	1	0.849	-15	6.95	105
	Mist blower	2	0.695	-45	86.9	225
	Mist blower	3	0.273	-45	0.503	210
Concho River (10708-2707) Samples collected 0.25 miles downstream	Mist blower	1	0.676	-15	0.813	0
	Mist blower	2	0.871	-60	0.589	150
	Mist blower	3	2.24	-60	7.45	15

Wide buffer strips (125-700 feet) with high vegetation appeared to reduce malathion drift to sensitive areas to levels below detection while narrower and lower buffer afforded less protection (Table 12). With aerial applications, 8 of 19 applications lead to higher aquatic malathion concentrations, whereas only 1 of 10 ground applications resulted in higher malathion levels. Thus aerial applications appear more prone to drift than ground applications. Although increased malathion levels in the streams, river and canals examined after nearby treatments decreased rapidly, decreases are likely due primarily to the movement of contaminated water downstream. To assess malathion stability in moving water a sampling station further downstream would be required along with measurements of the flow rate of the water.

Residential

Monitoring data suggests that urban malathion use poses the highest risk of contaminating surface water. However, use data is not available to correlate with monitoring data to determine which particular uses have the greatest impact. Total usage and use rates in specific cities is also unavailable. Targeted urban monitoring and preliminary fate experiments suggest however that malathion contacting anthropogenic surfaces is likely to convert to the oxon and has a high runoff potential.

Malathion concentrations in water in and around urban medfly treatment areas in California and Florida have been measured. Although risk assessment of malathion use for medfly control is not included in this document (these generally fall under section 18 local need uses) the monitoring studies associated with this use provide information on malathion fate and transport in residential settings. In urban areas

not involved in medfly control measures malathion can be found in runoff water at higher levels than agricultural areas. A monitoring report by United States Geological Survey showed that higher residue are found in urban areas. In this analysis of 11 urban streams (604 samples) and 37 agricultural streams (1530 samples) malathion concentrations were higher in the urban tributaries.

It is likely that proposed residential uses will result in aquatic contamination. Residential malathion use include outdoor home and garden, public park, and commercial use as well as residential mosquito control. Home use formulations may be applied as a "... spray to lower foundation of house, patios and garbage cans ... along fences; to firewood piles; and other infested areas." (Ortho Malathion 50 Plus Insect Spray label). Malathion on the surfaces described on the this label is likely to persist longer and be more available for runoff than malathion on soil. Fyfanon ULV formulation is applied at 0.2-0.23 lbs/A aerially at 150 mph over residential areas for mosquito control. In addition to covering anthropogenic surfaces it is likely that moderate sized bodies of water receive direct spray during normal aerial mosquito control use. In medfly treatments, malathion is mixed with a bait mixture and applied aerially at nearly the same rate as in mosquito control but with large buffers (up to 200 feet). Medfly applications in residential areas provide useful information on the fate and transport of malathion in these settings, but it is very likely that the smaller particles produced from the ULV formulation use in mosquito control results in more drift than the baited mixture for medfly. Thus, medfly monitoring data of drift will be expected to underestimate drift from ULV mosquito use.

In medfly control efforts larger bodies of water are "flagged" to avoid direct malathion treatment. Thus contaminated water bodies presumably received insecticide residues by drift and runoff. On average reservoirs in the treatment area which were flagged to avoid direct spray contained 0.16 ppb before treatments and 2.59 ppb immediately after treatment (Table 12). All waters in and around the treatment area, whether protected or not, showed increased malathion levels immediately after treatment. In general, applications were performed approximately weekly with no noted aggregate accumulation of malathion in water.

Rainwater runoff in California medfly treatment area contributed greatly to malathion levels in a stream passing through the treatment area. After precipitation, inflow into the treatment area contained less than 1 ppb while downstream water contained up to 203 ppb malathion. Maxima in 1990 and 1981 were 44.1 and 583 ppb (Environmental Monitoring Results of the Mediterranean Fruit Fly Eradication Program, Riverside County 1994).

Table 13 a Medfly spraying and malathion levels in bodies of water. Malathion was measured immediately before and after spraying a bait formulation at ~0.17 lbs ai/A from a altitude of 300 feet. This data was adapted from A Characterization of Sequential Aerial Malathion Applications in the Santa Clara Valley of California, 1981.

Aquatic malathion concentrations in ppb resulting from medfly applications												
site	treatment #	days since last spray	malathion					malaoxon (ppb)				
			no. of sample	before spray	S.d. Error	after spray	S.d. Error	no. of sample	before spray	S.d. Error	after spray	S.d. Error
Unprotected ¹ natural waters	1	*	14	*	*	4.94	2.71	*	*	*	*	*
	2	9	6-16	0.20	0.05	18.66	5.81	1	*	*	18.0	*
	3	11	13-15	1.50	1.17	9.78	2.47	*	*	*	*	*
	4	7	14-15	0.48	0.13	95.4	53.2	1-2	0.64	*	1.9	0.20
	5	7	13-14	0.66	0.12	4.97	1.05	4-5	0.19	0.046	0.63	0.17
	6	7	11-12	0.57	0.20	23.4	11.6	1-4	0.90	*	0.35	0.10
Average	-	8.2	-	0.68	0.33	26.19	12.81					
Protected ² natural waters	1	*	20	0.091	0.058	0.33	0.078	*	*	*	*	*
	2	9	20	0.12	0.07	0.56	0.10	*	*	*	*	*
	3	11	19-20	0.056	0.028	0.90	0.15	*	*	*	*	*
	4	7	14-15	0.12	0.07	1.25	0.22	*	*	*	*	*
	5	7	20-22	0.040	0.019	2.10	0.41	1	*	*	0.40	*
	6	7	15-19	0.053	0.040	0.39	0.089	2	*	*	0.45	0.25
Average	-	8.2	-	0.080	0.048	0.92	0.17					
Flagged reservoirs	2	9	2	0.18	0.03	0.75	0.65	1	*	*	2.7	*
	3	11	2	*	*	0.50	0.10	*	*	*	*	*
	4	7	19-20	0.033	0.024	8.39	3.81	2	*	*	0.92	0.29
	5	7	10-12	0.51	0.30	1.90	0.94	*	*	*	*	*
	6	7	8	0.075	0.062	1.42	0.41	1	0.1	*	0.83	*
Average	-	8.2	-	0.16	0.083	2.59	1.18					
Reservoirs outside treatment area	2	9	2	0.05	0.05	0.34	0.07	*	*	*	*	*
	3	11	2-4	0.10	0.10	1.0	0.55	*	*	*	*	*

	4	7	10	0.03	0.03	0.30	0.16	*	*	*	*	*
	5	7	10	0.036	0.024	0.14	0.058	1	1.3	*	*	*
	6	7	8-10	0.18	0.074	0.21	0.087	*	*	*	*	*
Average	-	8.2	-	0.079	0.056	0.40	0.19					

¹Unflagged and within the treatment area.

²Flagged to avoid treatment or outside the treatment area.

* No data.

Table 13 b. Malathion level in 29 ponds in Florida exposed to a.) direct or b.) indirect malathion spray in medfly control. Samples were collected within eighteen hours of approximately weekly treatments of 0.15 lbs/A. Unprotected bodies of water were ~0.1 miles in length and may have received runoff from surrounding watersheds. Protected waters were rivers or larger lakes. Statistically, values below the detection limit (0.1 ppb) were treated as 0 ppb and values below limit of quantitation (0.3 ppb) were treated as 0.15 ppb. The data was adapted from the Environmental Monitoring Report: Cooperative Medfly Project Florida, 1997.

a.)

Unprotected aquatic sites						
site	before			after		
	no. of samples	ave (ppb)	stdev (ppb)	no. of samples	ave (ppb)	stdev (ppb)
Fairgrounds	8	0.06	0.07	9	1.20	1.54
Palm river	9	0.78	0.72	7	3.97	3.24
Ragen Park	6	14.12	14.17	7	35.75	27.50
University Square Mall	7	0.04	0.07	7	3.77	3.67
Pond Lake	6	4.11	4.35	10	9.25	11.78
Bloomington Area	9	0.81	0.71	9	6.12	7.22
Carrollwood	7	1.05	2.01	6	4.77	3.75
Town and Country	6	1.10	1.15	5	6.88	3.07
McDill Site	5	0.12	0.06	4	5.20	2.33
Brandon Town Center	5	3.50	1.86	8	65.71	149.18
Lowry Zoo	7	0.14	0.22	6	1.55	1.86
Sun 'n Fun	8	0.09	0.07	10	7.28	15.48
Hamilton Creek	6	0.61	0.41	7	10.74	19.51
Eagle Lake	7	1.60	2.29	7	13.99	10.39

b.)

Protected aquatic sites						
site	before			after		
	<u>n</u>	<u>ave</u> (ppb)	<u>s.d.</u> (ppb)	<u>n</u>	<u>ave</u> (ppb)	<u>s.d.</u> (ppb)
Moore's lake	10	0.36	0.78	10	0.76	1.66
Lake Weeks	12	0.69	0.67	11	4.85	4.08
Lake Valrico	12	0.03	0.06	11	2.84	6.71
Lake Kathy	12	0.43	0.91	11	5.91	9.15
Lake Walden	6	0.21	0.14	6	2.21	2.37
Alafia River	6	0.13	0.17	6	1.93	4.06
Hillsborough River	8	0.35	0.39	8	5.02	9.13
Platt Lake	2	0.08	0.08	2	0.85	0.15
Lake Magdalene	2	0.08	0.08	2	0.80	0.20
Lake Carroll	2	0.31	0.16	2	1.65	0.55
Crystal Lake	9	0.02	0.05	9	0.46	0.74
Lake Horney	10	0.03	0.06	9	3.47	3.86
Banana Lake	7	0.21	0.33	7	2.48	3.97
Crews Lake	7	0.23	0.19	7	0.82	0.96

Residential settings are expected to be composed of numerous surfaces which may be physically and biologically impervious to malathion. The relative quantities and effects of adsorption and degradation on concrete, roofing, metal, and plastics is unknown in the residential settings where malathion may be sprayed for medfly and mosquito control. Monitoring results suggest that the residential surfaces increase availability of malathion for runoff probably due to lack of microbial activity which decreases metabolism, less water content which decreases hydrolysis, and little adsorption. Although the application rate for mosquito control is low relative to agricultural use (0.20-0.23 lbs/A for aerial mosquito control versus 0.18-6.25 lbs/A for agricultural pest control), application over wide areas may be concentrated in storm drain systems along with malathion from home garden and commercial site use.

The concentration factor appears to be greater in residential settings when comparing residential and agricultural runoff. This is consistent with the results of several USGS and USDA monitoring studies. Preliminary monitoring results for malathion in surface water (USGS 1997) show malathion was detected above 0.01 ppb with a 2.61% frequency in agricultural streams while in urban streams the frequency was 20.86%. The USDA monitoring studies for boll weevil control show an average runoff concentration of 15.5 ppb (Table 11) while average downstream creek concentrations in the urban Santa Clara Valley of central California were 177 ppb during 1981 malathion spraying for medfly.

The highest levels of aquatic malaoxon found in a search of available data was a result of medfly control efforts in California (CDFG 1982). The following table is derived from the monitoring study during th

malathion spraying in the Santa Clara Valley. Samples were taken 2-3.5 hours after the first rainfall 6 days after the last application. These runoff concentrations are much higher than agricultural runoff levels.

Table 14. Malathion and malaoxon concentrations in creeks after malathion applications in the Santa Clara Valley.

Sampling Location		malathion (ppb)		malaoxon (ppb)	
		average	sd	average	sd
Adobe Creek	50' upstream	449	17.7	164	33.2
	drain	583	40.3	328	18.4
	100' downstream	361	20.5	169	-
Stevens Creek	50' upstream	159	-	68.0	-
	drain	434	73.5	147	4.2
	150' downstream	156	23.3	68.0	-
Guadalupe Creek, site 1	50' upstream	1.9	0.2	0.8	0.3
	drain	142	-	147	4.2
	150' downstream	23.5	2.1	22.0	-
Guadalupe Creek, site 2	50' upstream	137	25.4	212	9.2
	drain	188	12.0	250	8.5
	150' downstream	169	6.4	231	8.5

Fate data for malathion clearly show that its major routes of degradation are through aerobic microbial metabolism and hydrolysis. Both of these routes are expected to be lower on inert, dry surfaces; thus malathion persistence would be expected to be increased. Malathion persistence on steel plates is extended relative to soil with only 15% lost in two days (State of California 1996) compared to several soils on which 50% can be degraded in 8 hours. Slowed malathion hydrolysis and metabolism is likely to result in increased malaoxon levels via abiotic oxidation. On the steel plate study mentioned previously, malaoxon accounted for 5% of the degradates, significantly higher than the maximum of 1.8% on soil reported by the registrant.

Limitations of Monitoring Analysis

Although a relatively large amount of monitoring data is available for malathion, the level of detail among the studies varies. Malathion is used on more than 60 crops and settings but detailed monitoring studies

were conducted mostly in conjunction with medfly and boll weevil eradication measures. Other studies lack important data such as detection limits, surroundings, wind direction, and rainfall data making comparisons between studies difficult. Though boll weevil eradication data may be considered to reflect malathion behavior on crops grown in the same geographical areas, more data is necessary to improve quality and to allow detailed statistical analysis. Malathion applications and monitoring associated with medfly control mostly occur in residential settings and thus are probably also representative of residential mosquito control in urban areas.

3. Ground Water Assessment

Malathion has some mobility characteristics similar to other chemicals that have been detected in ground water. In addition, malathion has been occasionally detected in ground water at levels ranging from 0.03 to 6.17 ppb.

USGS data in the National Water Quality Assessment show a malathion detection in ground water at > 0.05 ppb. The EPA Pesticides in Ground Water Data Base 1971-1991, National Summary reports malathion detections in ground water in California (1 detection out of 499 wells sampled at a concentration of 0.32 ppb), Mississippi (2 detection out of 263 wells, concentrations of 0.03-0.053 ppb) and Virginia (22 detections made in 9 of 138 wells samples with a range of concentrations of 0.007-6.17 ppb). All malathion detections in Virginia ground water were made in Westmoreland county as part of the Watershed/Water Quality Monitoring for Evaluating BMP Effectiveness program. Westmoreland is a coastal county and is approximately equally comprised of agricultural and forested land. Analytical detections in this study were conducted using gas chromatography with an electron capture detector and confirmed with flame photometric detector. Samuel Johnson of Westmoreland County Extension provided information on malathion use in this county. In recent years most of the agricultural malathion usage was for the control of cereal leaf beetle on barley and wheat. However, since 1995 a synthetic pyrethroid has replaced most malathion usage in Westmoreland. Mosquito abatement is not a major use of malathion in Westmoreland.

EFED believes these monitoring data illustrate that malathion has the potential for movement into groundwater, especially on soils with low organic matter and high sand content.

Cheminova disputes the ground-water data reported in the PGWDB. In particular, it calls into question the analytical methods used to generate the data in the Virginia study. In addition, Cheminova indicates that the maximum detection in the study was 3.12 ppb, not 6.17 ppb. Noting Cheminova's doubts for the Virginia data, EFED suggests a ground-water concentration estimate of 3.1 ppb for malathion for human-health risk assessment. This value is more conservative than SCI-GROW modeling results using maximal parameters for use on cotton (0.142 ppb). Since this monitoring result is specific for malathion EFED assumes the concentration of malaoxon will not exceed the concentration of malathion. Thus, EFED suggests conservative ground water concentration estimates of 3.1 ppb for malathion and 3.1 ppb for malaoxon.

The fact that malathion is detected in ground water means that under certain conditions it persists longer than its reported 1 to 3 day half lives emphasizing the need for further studies defining degradation rate under unfavorable conditions.